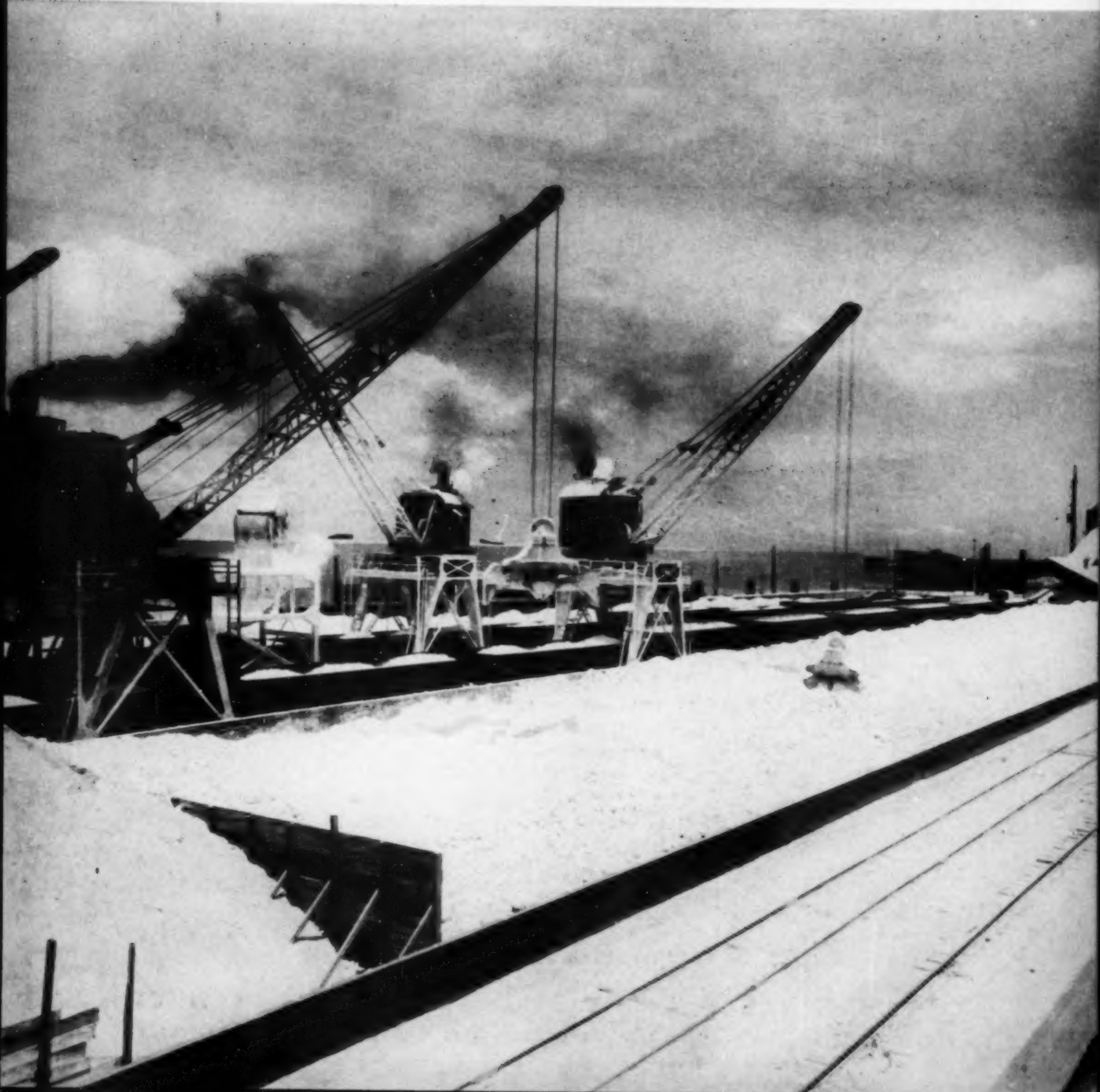
# MINING ENGINEERING

MAY 1951

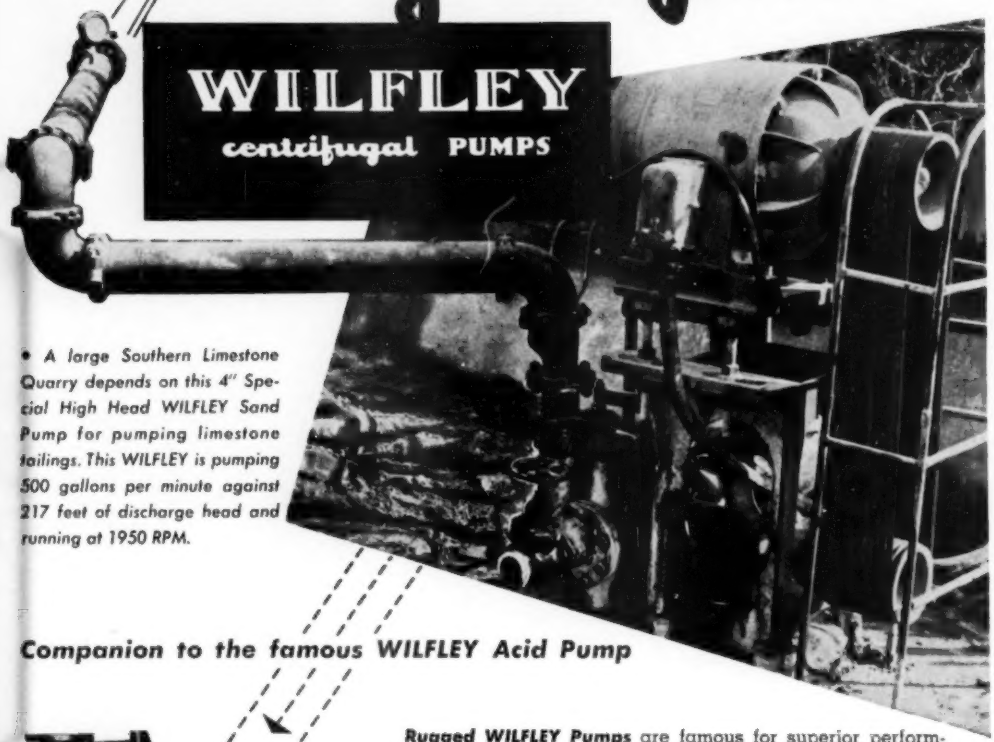


FOR

# tailings disposal

## WILFLEY

### centrifugal PUMPS



• A large Southern Limestone Quarry depends on this 4" Special High Head WILFLEY Sand Pump for pumping limestone tailings. This WILFLEY is pumping 500 gallons per minute against 217 feet of discharge head and running at 1950 RPM.

**Companion to the famous WILFLEY Acid Pump**

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Now the new WILFLEY Model K Centrifugal Sand Pump offers important mechanical improvements—engineering refinements which save you even more dollars on the production line and in power...give stepped-up performance and low-cost operation...easy interchangeability of wear parts and low maintenance. Investigate the new Model K for trouble-free, intermittent or 'round-the-clock service on your job. Every application individually engineered. Write or wire for Bulletin 200 on the new Model K.

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# MINING ENGINEERING

**Incorporating Mining and Metallurgy, Mining Technology and Coal Technology**

VOL. 3 NO. 5 MAY, 1951



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## FEATURES



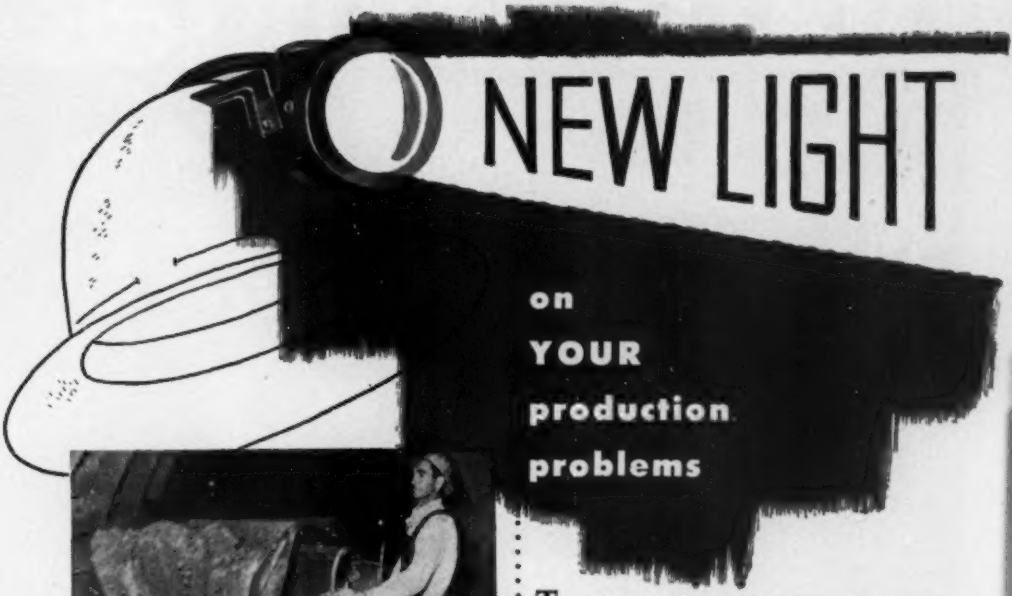
## ARTICLES



## TRANSACTIONS



**COVER: No $10,000 reward is being offered for the discovery of sulphur deposits in the United States, but this strategic mineral, shown being loaded into railroad cars at New Gulf, Texas, has more uses than uranium at the present time. The fertilizer, chemical, rayon, steel, paint, paper, rubber and oil industries are all concerned over present and future sulphur supplies.** **See P. 403 for the full story on where the sulphur will come from.**




*The "Big Bite" GD14 Mine Car Loader — for fast driving of tunnels or the larger mine headings.*

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# Save time on Pesky Jobs

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# Hornet Rock Drill

**... and your miners can put more work on production**

The H-22 Hornet is a terrific little rock drill. It weighs only 18 lbs., but it has all the design features found in larger Le Roi-CLEVELAND machines. That is why, pound for pound, you can't beat it for drilling speed.

And here's what your miners can do with it—easily and quickly, without strain: Drill holes for trolley hanger bolts. Clean up roof. Clear out rock falls. Brush bottom. Drill oversize pieces at the grizzly. Cut hitches. And a thousand and one other odd jobs.

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RD-34

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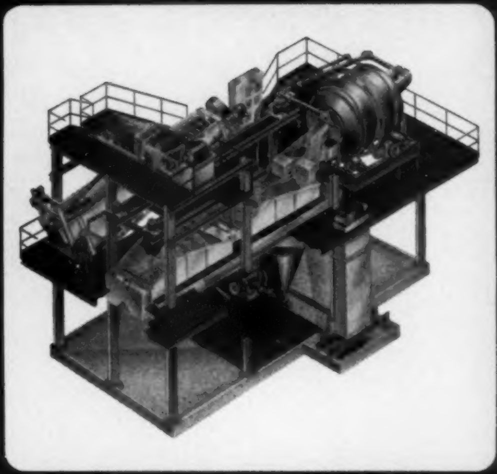
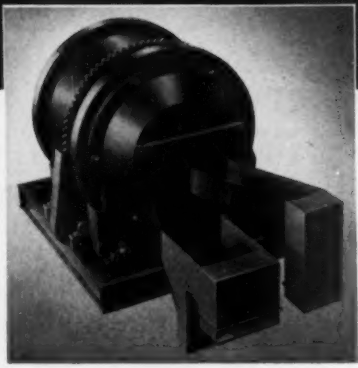
Greater separating [illegible] ble performance [illegible] Mobil-Mills using the [illegible] rators. The higher [illegible] lower capital investment [illegible] newest improvements [illegible] WEMCO leadership in Heavy-Media [illegible]





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For one stage Heavy-Media Separation, the single drum provides positive sink removal, low attendance requirements, close control of media density and lower horsepower consumption.

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In a typical operation, feed is received by the first compartment which overflows a true float product and sends sink material directly to the second compartment. There a heavier gravity medium floats the middling product and submerges the true sink.

Both the true sink and true float are purer products than those produced by single stage operation, and the middling is cycled to recrushing and further separation.

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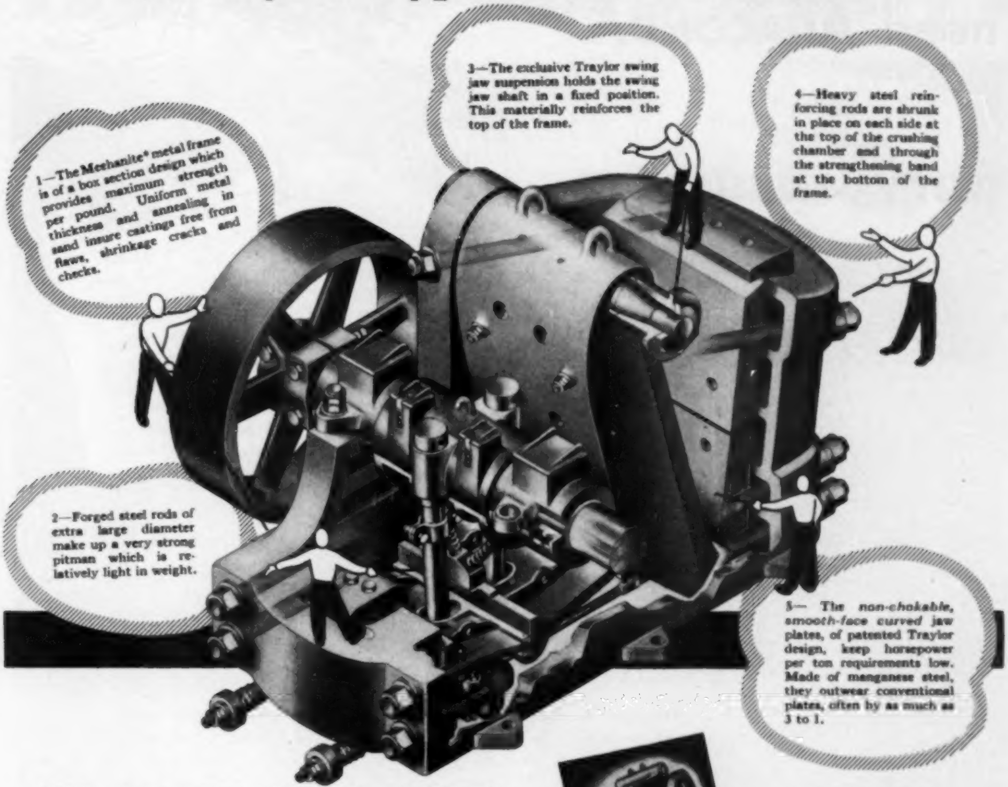
# "Advanced Design" is written all over a Traylor Type R Jaw Crusher




This cut-a-way illustration of a Traylor Type R Jaw Crusher exposes its many advanced design features. Each of these many features contribute to larger profits by increasing production while cutting power and maintenance costs. The Traylor Type R Crusher is a modern breaker of massive proportions and sturdy construction . . . designed for heavy-duty service under the most severe operating conditions. For more complete information on one of the best primary crushers available, mail coupon for free bulletin on a Traylor Type R Jaw Crusher.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**345 MILL ST., ALLENTOWN, PA.**

I would like to have complete information on Traylor Type R Jaw Crusher.

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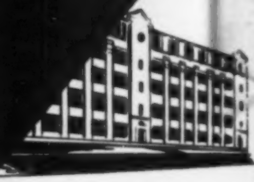
Recent discoveries may furnish the clue to economic operation of your development projects under present conditions. New Cyanamid Reagents added to or substituted for traditional reagents may provide the required recovery at permissible costs. The use of Heavy-Media Separation or the Dutch State Mines Cyclone Separator Processes may make the difference between profit and loss on lower-grade ores.

It is not one day too early to find out what Cyanamid can do to help. Starting point is a discussion of your problem with the Cyanamid Field Engineer in your district, so that he can bring to bear all the resources of the Cyanamid Mineral Dressing Laboratory on its successful solution. Your letter or telephone call will receive prompt and intelligent attention.



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VISION

30 ROCKEFE YORK 20, NEW YORK

*Printed in U.S.A.*

# Meet The Authors

R. C. AMERO — D. M. BONDURANT — D. W. MITCHELL — J. RYAN — W. L. SWAGER — J. D. SULLIVAN

**R. C. Amero** (*Fullers Earth—A General Review*, P. 441) is a chemical engineer, with a B.S. from the University of Rochester. After holding various positions, including that of technical director, with the Floridin Co. in Warren, Pa., he joined Johns-Manville Corp., and is now senior research engineer on a pilot plant project for the Celite (diatomaceous earth) division. Mr. Amero is an AIME Member.

**D. M. Bondurant** (*Primary and Secondary Mining with Auger Equipment*, P. 431) is assistant professor of mining engineering at West Virginia University. He came to his teaching post via the Brownfield Coal Co., where he was a mining engineer, and the Jeffrey Mfg. Co., where he served as installation engineer. He's an Ohioan, born in Uniopolis and a graduate of Waynesfield High School, and has his bachelor's degree from Ohio State University.

**H. B. Foxhall** (*Southwestern Industrial Minerals*, P. 412) until recently headed the division of geology of the Arkansas Resources and Development Commission. On March 1 he resigned that post to become a consulting geologist in Houston, Texas. He has been in geological work since 1942, when he took his M.A. from Leland Stanford University. As a USGS geologist he mapped Arkansas bauxite deposits, did strategic minerals investigation, and did intelligence work with a military geology unit cooperating with the U. S. Corps of Engineers from 1945 to 1951. Mr. Foxhall, an AIME member, took his B.A. from the University of Texas and his M.A. from Leland Stanford.

**H. H. Hasler** (*Simultaneous vs Consecutive Working of Coal Beds*, P. 436) has been with the Pennsylvania Coal & Coke Corp. since his graduation from Lehigh University, and is now chief engineer. He was born in Ashland, Pa., and attended high school there. Mr. Hasler was an Institute member from 1920 to 1934.

**O. R. Lyons** (*Predicting and Comparing Results When Dewatering Coal by Centrifuges*, P. 417) recently became coal preparation engineer and manager of preparation for Republic Steel in Cleveland. Previously, he had been a coal preparation engineer with Heyl & Patterson, a research engineer at Battelle Memorial Institute, and a junior engineer with Philadelphia & Reading Coal & Iron. Born in Staples, Minn., Mr. Lyons attended high school in Grand Forks, N. D., and went to the University of North Dakota and the University of Alabama. He holds a B.S. in mining engineering, a B.S. in geology, and an M.S. in mining engineering. AIME member Lyons has presented three other papers before the Institute.

**D. W. Mitchell** (*Factors Influencing the Choice of a Loading Machine*, P. 426) was born in New York City, attended Townsend Harris Preparatory School, took his B.S. from Penn State and his M.S. from Columbia. For the past 6 years he has worked as a face laborer with the Hudson Coal Co., as a surveyor with H. C. Frick Coke, and has done mining research work at Columbia University. Mr. Mitchell is a Junior Member of AIME.

**J. Ryan** (*Industrial Salts: Production at Searles Lake*, P. 447) is with American Potash and Chemical's lake development section in Trona, Calif., and has been with the company for 9 years. He has a wide background in research and development work, including development of the lithium recovery process, work on boron beneficiation, and lake development of mineral resources. From 1939 to 1942 Mr. Ryan was in the research department of the Hudson Bay Mining & Smelting Co., Flin Flon, Manitoba, working on numerous projects in the minerals beneficiation field. He holds a chemical engineering degree from Notre Dame.

**John D. Sullivan** (*Sulphur*, P. 403) is a noted AIME member, having served the Institute in eleven different capacities since 1931. From 1948 to 1950 he was a Director of AIME. Now assistant director of Battelle Memorial Institute, Mr. Sullivan has been with that organization since 1931, when he became chief chemist there. Prior to that year he had worked at the Bureau of Mines Northwest, Pacific, and Southwest experiment stations. Mr. Sullivan attended the University of Montana, and took his B.S. and M.S. in chemistry from the University of Washington. He also did graduate study in physical chemistry at the University of California and in mining administration at the University of Arizona. He is a member of the American Ceramic Society, was president of that group in 1947, and was on the board of trustees from 1940 to 1950. In addition, he is a member of the American Foundrymen's Society, the ASTM, the London Chemical Society, Sigma Xi, Phi Lambda Upsilon, and numerous other scientific and professional groups.

**W. L. Swager** (*Sulphur*, P. 403) is assistant supervisor, engineering economics division, Battelle Memorial Institute, Columbus, Ohio. Before joining Battelle he had held various positions in New York, Buffalo, and Marcus Hook, Pa., with Allied Chemical and Dye. Mr. Swager took his B.S. in chemical engineering from Purdue in 1942.

## Personnel Service

THE following employment items are made available to AIME on a non-profit basis by the Engineering Societies Personnel Service, Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York Office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

### MEN AVAILABLE

**Geologist,** BSc, MSc, 27; married, 2 children; excellent health; 3 years as operational and field geologist in Chile, Bolivia, Peru, Venezuela. Experience includes mapping, sampling, prospecting for metallic and nonmetallic deposits, directing drilling programs, etc. and supervising other geological work. Fluent Spanish. Desires permanent responsible position preferably abroad. M-619.

**Mining Geologist,** Ph.D. geology and graduate mining engineer. Ten years' experience geologic mapping, mine examination, exploration and development of metallic and nonmetallic mineral deposits, both domestic and foreign. Experienced report writer. Speaks Spanish. Seeks permanent connection in mining exploration. Married, good health, employed, excellent references. M-620.

**Recent Graduate,** 27, single, B.S. degree in geology. Desires position as junior geologist. Will travel anywhere in Western Hemisphere. Available immediately. M-621.

**Metallurgist,** 38; 14 years' experience flotation, roasting-leaching plants and research; sulphides, tin, tungsten, nonmetallics; B.S. mech. engrg. M-618.

### POSITIONS OPEN

**Mining Engineer,** to work in the technical end of conveyor belt division. Some mining experience or experience with belt conveyors in mining operations advantageous. Will, after training, make outside contacts with companies in connection with requirements for conveyor belts. Salary, $3600-$4200 a year. Location, Ohio. Y5199D(b).

**Geologists**—Large corporation desires services on permanent basis of several senior geologists, having 5 to 10 years' experience in mineral examination and exploration work. Salary open, commensurate with experience. Apply by letter. Location, domestic and foreign. Y5182.

**Sales Engineer,** 26-35, metallurgical engineer, to sell flotation, heavy media separation and grinding equipment in New York export office. Salary, $4200-$6000 a year plus bonus. Y5129.

**Mine Superintendent,** graduate mining engineer, with considerable experience in operation, mine planning, and handling of men. Must be experienced in the use of Joy loaders and shuttle cars and know low-seam room and pillar method of mining. Prefer a man with low-seam gypsum mining experience, but will consider a man with low-seam coal experience. Location, upstate New York. Y4992.

**Assistant Mine Superintendent,** mining graduate, experienced in open-pit mining and familiar with operation and maintenance of heavy mining equipment such as churn drills, electric shovels, diesel trucks and tractors. Salary, $4800-$6000 a year depending on experience. Opportunity for advancement within a two-year period. Applicant should be married, not subject to the draft or recall to duty in the Armed Forces. Location, New York State. Y4982.

**Junior Metallurgist,** recent graduate, with two to three years' experience in flotation, to assist flotation plant superintendent, including some work connected with the mining of phosphate rock. Work will be strictly night operations. Location, Florida. Y5113.

**Mill Shift Boss,** single, metallurgical graduate. This is a cyanide process treating silver and gold ores and has an average capacity of 565 tons per day. Salary, $2400 a year, plus room and board and transportation to the mine. Two-year contract with return passage and two months' vacation. Location, Central America. Y5014.

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**Designers, Draftsmen Wanted**

Designers & Draftsmen with experience in ore dressing plants, smelters and related machinery wanted for permanent positions with active engineering and manufacturing organization. Location: Eastern, Middlewest, West. Salary based on experience. Mail full details of training and experience to P-4, MINING ENGINEERING.

**GRADUATE MINING ENGINEER**

30 to 40 years of age. Must have broad experience in general coal mine engineering, will assume charge of underground surveying, map work and general engineering as assistant to plant engineer. Mine completely mechanized, located at Harewood, W. Va. Give experience, education, age, references, personal history. Be complete and specific. All inquiries will be handled promptly and confidentially.

SEMET-SOLVAY DIVISION

Allied Chemical & Dye Corporation

Box 670 — Bluefield, West Virginia

### Explosion-Proof Motors

A completely new line of explosion-proof mining motors, conforming to Bureau of Mines Schedule 2E, has been announced by General Electric. They represent the results of a

survey of mining personnel, and are available in ratings from ½ hp through 60 hp at 230, 250, 500, and 550 v. Inspection is facilitated by making all brushes accessible through two large handhole covers. Cable replacement without removal of the end shield or working through commutator access openings is possible. Standard models are foot-mounted, but they can be supplied without feet for strap mounting, or with a face or flange end shield. **Circle No. 1**

### New I-R Wagon Drill Features Flexibility

Unlimited drilling positions of the tower or drill guide are possible with the new FM-3 Ingersoll-Rand wagon drill. The yoke can be low-

ered within the frame itself, placing the drill in the lowest desired position for toe hole work. A worm and pinion gear actuated by a ratchet handle permits rapid raising of the drill for higher holes. Vertical drilling close to the face is simplified because the drill extends out beyond the limits of the carriage when the swivel-mounted wheels are turned 90°. The drill handles 6-ft steel changes with bits up to 4-in. gage, and is good for holes up to 24 ft. **Circle No. 2**

### Straub Expands Markets

Straub Mfg. Co., Oakland, Calif., makers of Kue-Ken crushers and Straub mining machinery, has made a license arrangement with Sir W. G. Armstrong Whitworth & Co., in England for production and distribution of Straub machinery. The Whitworth territory will include Great Britain, Èire, Europe, South Africa, India, Pakistan, Australia and New Zealand. **Circle No. 3**

### Tractor, Shovel, Combined

A complete, integrated design of track-type tractor and shovel, marking an improvement over the front-end attachment generally used on crawler tractors, has been announced by the Frank G. Hough Co. The engine is mounted at the rear, for maximum stability, and the operator is high and forward for good visibility. Transmission provides four forward and four reverse speeds. Bucket capacity is 1 cu yd, with boom arms and bucket dump controlled by double-acting hydraulic rams. Horsepower is 67, in either gasoline or Diesel models. **Circle No. 4**

### New Magnetic Separator

More selectivity and greater capacities in the concentration of weakly magnetic materials such as manganese, pyrrhotite, ilmenite, chromite, etc. is said to be possible with the new Dings Cross-Belt magnetic separator. Material to be separated is carried on a main belt conveyor below magnet and cross belt assemblies. Magnetic particles are attracted to the cross belt, which moves them to the side, to be separately discharged. Each cross belt can be adjusted separately, as the cross belt assemblies are individually energized. **Circle No. 5**

### Centrifugal Pump Data

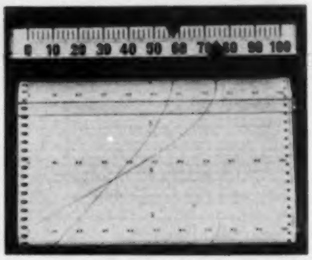
An informative guide to pumping units for every industry has been issued by the Allis-Chalmers Mfg. Co. The new 16-page publication covers electrifugal, SS, pedestal-type, double suction, multi-stage, self-priming, process, solids, and mixed flow pumps. Complete information on sizes, capacities, motors, applications, and construction features is offered. Head-capacity tables indicate pump size, type, horsepower, and dimensions when total head and gpm capacity are given. **Circle No. 6**

### H-M Coal Separation

A detailed 36-page report entitled "Heavy-Media Processes for Coal Preparation" has been published as one of the American Cyanamid Co.'s "Mineral Dressing Notes." The publication presents the advantages of Heavy-Media Separation, standard flow sheet, effect of feed variations, full-size range treatment, recovery of near-gravity coal, and magnetite. In addition, there are descriptions of seven representative Heavy-Media Separation plants in operation, and information about the products of five fabricators of commercial Heavy-Media plants and separatory vessels. A bibliography and a description of an H-M Separation pilot plant are appended. **Circle No. 7**

### Dual Technical Records

Simultaneous recording of both radioactivity and rock strata resistance in underground drilling operations is now possible with a new electronic recording instrument de-




veloped by Minneapolis-Honeywell. The same device may also be used for spectrometer analyses. The two-pen recorder eliminates the two 'passes' formerly required for obtaining drilling data, by making two simultaneous recordings. Correlation of the recordings is automatic. **Circle No. 8**

# Free Literature

**(9) PORTABLE LIGHT LINES:** Twelve-page bulletin #SL202 in which many combinations and variations of Joy String-a-lite lighting and tap-off assemblies are pictured and described has been issued by *Joy Mfg. Co.* These sectionalized assemblies simplify installation, reduce maintenance and increase safety of temporary installations.

**(10) HEAT EXCHANGES:** Designed for transfer of corrosive liquids, hot or cold. Outstanding features of these versatile units are durability, light weight, flexibility, and low price. Pictures and illustrations explaining these points are included in this booklet available from *Nuken Products Co.*

**(11) SOIL TESTING:** New products catalog covering new additions in soil testing apparatus line. Among some of the items illustrated and described are new models of triaxial and consolidation apparatus and accessories, paraffin warmers and dispersion mixers. This 12-page catalog #3-51 is issued by *Soil Testing Services, Inc.*

**(12) DIMENSIONAL DATA CARD:** Dimensions on welding fittings and flanges have been condensed and reproduced on this card offered by *Taylor Forge & Pipe Works.* One side of card explains the broad WeldEll line of welding fittings. The other side of card gives essential dimensions and bolting data for all types of flanges, in all weights, for nominal pipe size from ½ in. to 30 in.

**(13) ARIDIFIER:** This pamphlet explains how Aridifier cleans and dries compressed air and removes 92 pct of oil, water and dirt from gas and air lines. The Aridifier's multi-bladed rotors are made of durable molded plastic in smaller sizes and of aluminum in the larger sizes. Bulletin 1150 issued by *Logan Engineering Co.*

**(14) PRECISION POWER SAW:** Completely new approach to the problems of power sawing heavy roof and support timbers for mines. Among some of favorable features claimed by *Wright Power Saw & Tool Corp.* are blades that can be changed in seconds and because of simple rugged construction the saw is virtually trouble free.

**(15) FLEXIBLE COUPLINGS:** A new 4-page illustrated folder 2363 has been issued by *Link-Belt Co.* on "RC" roller chain flexible shaft couplings. Engineering information for proper application includes dimensions, weights, service factors and horsepower ratings.

**(16) CONVEYOR AND ELEVATOR BELTING:** Contains a discussion of each of various types of belting and suggestions for their application and is complete with necessary tables, charts, and formulae for the selection of the right type of belt for the application. This 16-page booklet is issued by *Thermoid Co.*

**(17) RECORDER BULLETIN:** Bulletin C2-2 describes *Wheelco Instruments Co.'s* line of electronically operated strip chart recorders. The bulletin also lists model numbers and specifications of the various recorders and recorder-controllers.

**(18) ELECTROLYTIC CLEANING:** Revised edition of booklet has been published by *DuBois Co.* containing information on fundamentals of electrolytic cleaning, phenomena that takes place during cleaning, considerations in choice of electro-cleaner for any particular process and other pertinent data. Cleaning cycles and several case histories of actual plant operations are given. New information included in this edition are the cleaning of die-cast metals, the cleaning of cuprous metals including reverse current cleaning, without discoloration, soaker tank cleaning and paint stripping.

**(19) AUTOMATIC DUCKBILL:** Patented mechanical loading head for use with shaker conveyors is described in bulletin CC-508 obtainable from *Goodman Mfg. Co.* It makes possible a continuous flow of coal from face to entry loading zone. The Duckbill will operate efficiently under conditions of bad roof, low height and close timbering. Illustrations are included showing actual use. The assembly unit is shown in cross-section with various component parts.

**(20) PIPELINE TRACTOR:** Specifications for tractor and engine for *Caterpillar Tractor Co.'s* Trackson MDW8 Pipe Layer and No. 46 Hydraulic Control are contained in booklet 30135. Travel speeds, lifting capacities as they vary with overhang of the pipe layer and details on the offset track arrangement are included.

**(21) REAR-DUMP:** Models 80FD and 82FD Rear-Dump of 15 ton capacity are described in 8-page *Euclid Road Machinery Co.* catalog. Bulletin describes various features of the off-highway hauling units designed and built for moving earth, rock, ore, and other heavy excavation. Powered by Cummins 165 hp or General Motors 190 hp diesel engines, top speed of this unit with 30,000 lb payload is 21.5 or 26.4 mph.

**(22) HYDRO-CHECK:** Users of air cylinder will be interested in pamphlet HC-600R available from *Bellows Co.* It illustrates and describes the Bellows system of using an opposed hydraulic force to smooth out the natural bounce of air. The Hydro-Check sets up an opposed, steadying resistance to the thrust of air cylinder pistons, providing a piston rod movement of exceptional smoothness.

**(23) RETAINING WALLS:** Photographic descriptions illustrate how these bin-type walls are simply and economically installed with a minimum of excavation in reference manual published by *Armco Drainage & Metal Products, Inc.* Technical data on selection of design, and units required for various types of sections as well as sketches showing typical applications are also included. In addition, use of the walls on curves and grades is also shown.

**Mining Engineering** — May
**29 West 39th St.**
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There is plenty of sulphur available but not at the price currently being paid for brimstone. Immediate shortages may be felt before the market adjusts, making marginal sources and by-product sulphur and acid available. (See P. 403)

Government aid for mineral exploration is available and regulations governing applications are available from The Defense Minerals Administration, Dept. of Interior. Just ask for MO-5 and also for the contract form which is MF-103.

The $100,000 enterprise of Coosa Cassiterite Corp. is expected to yield 250 tons of tin per year from Alabama pegmatites. The deposit, which is being mined on a 15 mile strip on a line between Birmingham and Montgomery, assays from .5 to 30 pct tin. Concentration, after crushing, is by air tables which make a 70 pct concentrate. Other materials such as mica, feldspar, and titania are being recovered.

1950 world production of tin concentrates, totaling 163,500 tons, was less than the 1935-39 average of 171,600 tons. Tin metal production was 172,500 tons, up from 168,000 tons in 1949. Consumption was 147,000 tons compared to 118,800 tons in 1949.

Suffering from restricted sulphur shipments from U. S., the British Government on March 28 approved erection of a plant to produce sulphuric acid from gypsum. About 150,000 tons of acid per year will be produced when the plant is completed in 2 years.

Southwest Potash Corp. expects to begin production in the latter half of 1952. The mine and mill will be capable of handling 2500 tons per day, which will be treated by flotation to produce KCl. The mine is located near Carlsbad, N. Mex.

At the Wabana iron ore properties of Dominion Steel new developments include the adoption of Drill-Mobiles and jacklegs for drilling replacing post-mounted Leyner drills, and plans for a 1000 ton per hr, 12,000-ft slope belt conveyor.

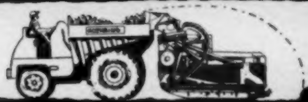
It will take fifty four 1600-hp Diesel locomotives to transport the 10 million tons of Labrador ore from Ungava to the St. Lawrence.

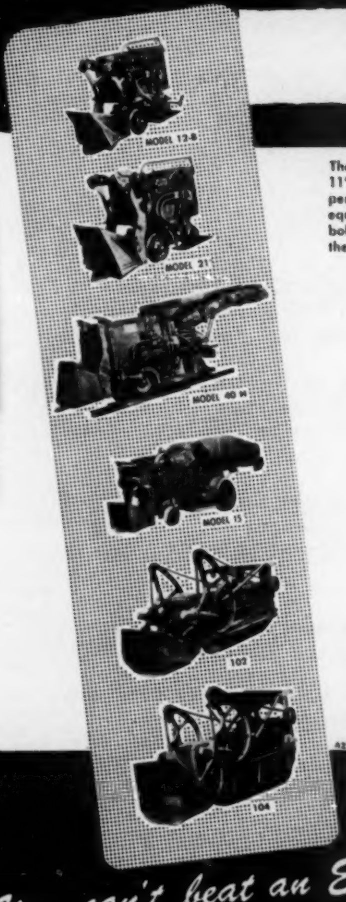
A huge discovery of vermiculite at Stanleyville, 8 miles southwest of Perth, Ont., will probably make Canada independent of foreign sources of this material. The major portion of the new discovery, which measures approximately 3000 ft long by several hundred feet wide, has been taken up by commercial interests.

# CASE HISTORY OF A SUCCESSFUL TUNNEL JOB

**FROM THE EIMCO FILE T270**

## KEYHOLE DAM TUNNEL




The Keyhole Dam outlet tunnel near Moorcroft, Wyoming 654' in length. Approximately 11'x12' arched cross section. Tunnel driven in 35 shifts. Average round 8.06 ft. 2.33 rounds per shift. 33.15 — 9' holes per round. Average 2.66 lbs. powder per cubic yard. Loading equipment—Eimco 102 RockerShovel. One interesting fact about this tunnel is the use of roof bolting instead of steel or wood sets. Using 4.40 ft. of Roof Bolts for each foot of tunnel the contractor was able to make exceptionally good time. Haulage units used were Dumptors.

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# Let's Do Our Own Research

GROWTH of the United States to industrial supremacy in the world is mainly because of the rapid exploitation of natural resources. The easily found high grade mineral resources have been depleted and attention has turned to low-grade ores. Progress has been made from the comparatively crude mining and milling techniques, which sufficed for the rich deposits, to more complex technology for exploiting low-grade ores. In spite of this progress the defense program is pointing up the fact that the mining industry is caught short on ability to produce the needed mineral raw materials. The mining industry is digging itself out of business here in the United States.

This statement is supported by pointing to the increasing rate of investment of American mining companies in the foreign field. Such staples as iron, copper, lead, and zinc are showing up in unprecedented tonnages on the annual list of imports. Government support is evidently needed for many of the new mines that will be coming into production in the next few years. Companies not previously in the mining business are entering the field. Other companies, only on the fringe of the mining field, are working out processes which are strictly of a mineral extraction nature. If some changes are not made, the future may see the old established mining companies interested primarily in the foreign field while interlopers from other industries are doing the job of mineral exploitation at home. To prevent this from happening, research on methods and research on mineral utilization and markets is needed. The mining companies must aggressively go out after new business the way manufacturing companies do. Few mining companies have established research departments for mining and ore dressing work. The industry has come to rely on manufacturers, research organizations, universities, and the government for the conduct of research. This seems like a formidable array of research institutions but in reality a direct approach by the mining companies themselves is needed. The petroleum, chemical, and electrical industries devote tremendous sums to production and process research as compared to the mining industry. Processes which could mean increased profits and new business for mining companies are being developed by companies that are on the fringe of the mining field. Striking examples are the development of jet piercing by Linde Air Products and the new process for treating low-grade sulphur deposits which has been announced by Chemical Construction. In the nonmetallics field many new types of minerals have become economic in recent years but the initiative in these ventures frequently has been from outside interests, such as building contractors.

The mining industry is short on technical manpower for the research work. Comparatively few engineers have advanced degrees. Many who take advanced degrees in extractive metallurgy go to work for chemical companies because they offer better opportunities for development work and research. These facts are indicative of the attitude of the mining industry toward research. The attitude which keeps these young men from going into the mining field or taking advanced degrees is the same that withholds money from long-range research projects.

Many opportunities exist for mining development in the United States, awaiting only a new approach. These questions may be asked: Are existing methods and processes adequate in the light of new scientific discoveries and new and improved equipment? Can a market be found or developed for a specific mineral product? The mining companies can be just as aggressive in going after new business as those in other fields if they are backed by research organizations that can find the answers to these two questions.

# Trends

*A REPORT OF CURRENT ACTIVITY IN THE INDUSTRY*

WASHINGTON continued to take a lively interest in the development of mineral resources last month, and called for more funds—$208 million to be exact—to loan to mineral producers, coal and coke producers, and oil refineries. DPA Administrator W. H. Harrison told a House committee that mineral purchase programs involving $4,460,000 worth of chromite, beryl, columbium-tantalum, manganese and mica will go into effect before June 1; and that DMA will contract for $336 million worth of chromite, cobalt, fluorspar, manganese and nickel for delivery after June 30.

DMA Administrator Boyd said that the Government is considering loans to the Falconbridge Nickel Co. to build a refinery in Canada or the U.S.; to the Copper Range Co. for expansion at White Pine, Mich.; and to other domestic producers of antimony, chromite, fluorspar, iron ore, manganese and zinc.

• **The Government's Controlled Materials Plan** (CMP) will go into effect on July 1, affecting virtually the entire economy with the exception of consumer durable goods. CMP will channel the three basic metals—steel, aluminum, and copper, into the production most necessary to the defense effort. Producers of a selected list of materials, including machinery and component part manufacturers, will be called upon to file their requirements soon after May 1. The NPA will release the list, along with instructions, shortly. Products will be divided into two categories, "A" and "B". Producers of "A" products will get production authorizations and material allotments from their customers. "B" product manufacturers—such as producers of civilian products, industrial machinery, etc., will obtain allotments from the NPA.

• **Hearings were held on Apr. 4, 5, and 6 by the** Mines and Mining Subcommittee of the House Interior and Insular Affairs Committee to determine what is being done to stimulate exploration and development of strategic minerals; why there have been delays in executing necessary programs; the authority of each agency having jurisdiction in the minerals program; and policies and decisions rendered by each agency in the program. Rep. Clair Engle, (D., Calif.) said he hoped to discover "whether the defense minerals production program is as complete and dismal a flop as it is believed to be in the far west." This was a reference to hearings held in Phoenix, Ariz., and Ely, Nev., at which small mine operators appeared dissatisfied with the DMA program and urged a program comparable to the World War II Premium Price program. DMA administrator James Boyd said his agency had processed 21 procurement contracts, calling for greater production of aluminum, copper, zinc, molybdenum, titanium, manganese, tin, cobalt, and tungsten. "DMA has also recommended," said Mr. Boyd, "approval of 61 certificates approving accelerated tax amortization totaling more than $490 million." But Rep. Engle spoke of the "hopeless failure" of the present program and noted that only two contracts for minerals had been put into effect since the Defense Production Act was passed.

• **The search for radioactive minerals in Alaska has** been stimulated by the approval, by the Alaskan legislature, of a $10,000 bonus for the discovery of such minerals in the Territory. It will be given in addition to the recently increased Atomic Energy Commission award. Three areas of radioactivity in Alaska were reported during 1950—in the Hyder district, in South Central Alaska, and on the Seward Peninsula.

• **A multi-million dollar sulphur mining plant will** be built at Bay Ste. Elaine dome in Terrebone Parish, La., by the Freeport Sulphur Co. Work will begin at once, and is expected to be finished in 2 years. The entire plant will be built 75 miles away, floated to the site on barges, and then sunk into place. This is being done because half of the dome is under water and the remainder consists of unstable marshland. Mined sulphur will be barged in liquid form to Port Sulphur for storage.

• **Forty European ore dressing experts are in the** U.S. for a 7-week study of American milling methods and practices, under ECA auspices. Paul M. Tyler, formerly of the Bureau of Mines, planned the tour for the visitors. They will visit laboratories and ore testing plants in New York, the American Zinc plant at Mascot, Tenn., and the Tennessee Copper milling operations. The group will then break up into three teams—one interested in lead and zinc ores, one in copper ores, and the third in iron and nonmetallic minerals beneficiation. Each group will visit leading operations in both the U.S. and Canada.

• **The railroads are unhappy about the proposed** St. Lawrence Seaway, as witness the testimony of the counsel for the Assn. of American Railroads, who told the House Public Works Committee on Apr. 2 that the Seaway is not needed for national defense, that it is detrimental to the economy, vulnerable to enemy attack, and not needed for bringing in Labrador ores because "there is a reserve of more than 30 years in the Mesabi Range, and in addition to that there are other sources of iron ore."

• **On April 6 the House passed and sent on to the** Senate the Mills Bill, suspending the copper import tax from April 1, 1951 to Feb. 15, 1953. The bill also provides that the President must reimpose the tax within 35 days if the average price of electrolytic copper falls below 24c per lb for any calendar month.

• **A $2 million chrome smelter and refinery will be** built by Chromium Mining & Smelting Corp. Ltd. of Canada, at Glendive, Ariz. The company is now considering the possibilities of establishing a large scale manganese operation in the Butte district, and

is said to be negotiating with the Government for an option on the Benbow chrome mine, south of Columbus, in Stillwater County. During World War II, the Government produced over 100,000 tons of chrome concentrates from the mine, and invested $20 million in equipment for it. Most of the equipment, however has been sold and removed.

• **About 55,000 tons of ore with an iron content of** 54 pct have been taken since Mar. 1 from a pit on the Cuyuna Range near Randall, Minn. The Pacific Isle Mining Co. has been operating at the site since January, and sending carload samples of the ore, and of 40 pct ore, to Hibbing beneficiation plants. G. M. Schwartz, director of the Minnesota Geological Survey, has said that there may be possibilities "of a good-sized operation."

• **The National Inventors Council of the Depart-**ment of Commerce is calling upon engineers to help solve a few important national defense problems. Among those problems the Council is seeking answers to are: An accurate instrument and technique for barometric leveling; a technique, method and equipment for the detection of buried explosives; rapid, automatic methods of determining the size of smoke particles and the obscuring power of the smoke; methods for dispersing liquids and solids as a stable aerosol without decomposing the material being dispersed.

• **The first of two shafts soon will be sunk at Beth-**lehem Steel's new mining site near Morgantown, Pa., according to president A. B. Homer. The deposit, 30 miles from the company's Cornwall mines, lies at a depth of 1500 to 3000 ft below the surface. Ore is of the magnetic type and can be concentrated into a product with an iron content of 60 to 70 pct, making it suitable for either blast furnaces or open hearths.

• **The United States may become self-sufficient in** certain rare-earth minerals if deposits near Mountain Pass, San Bernadino Co., Calif., come up to expectations. USGS geologists have discovered veins and bodies of barite-carbonate rock in an area 6 miles long and 2 miles wide, extending southeast from the original discovery, made late in 1949. A single deposit, if it extends to a depth of 100 ft, may contain 50,000 tons of rare-earth bearing minerals, principally bastnäsite.

• **Republic Steel is exploring for iron ore in Vene-**zuela's richly-endowed State of Bolivar, where U.S. Steel's Cerro Bolivar and Bethlehem's El Pao deposits are being developed. Republic's tests are being made on private concessions west of the Caroni River and north of Cerro Bolivar. The concessions were granted to a Venezuelan citizen in 1946, before the government declared remaining land to be a federal reservation. A company spokesman reported that Republic is exploring for M. A. Hanna, and Jones & Laughlin, as well as itself.

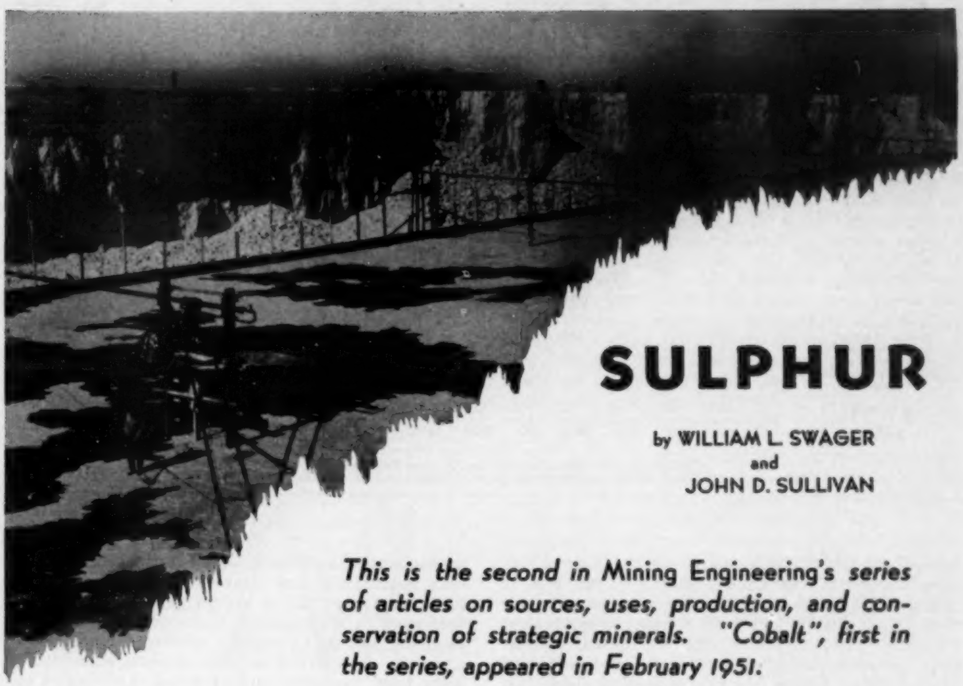
• **To bridge the gap between the campus and in-**dustry, duPont is giving educators from engineering schools 12 months' experience throughout its entire engineering organization. Their regular salaries, plus expenses, will be paid by the company. D. L. Arm, dean of the University of Delaware's School of Engineering, was the first to enter the program, beginning in April. Additional appointments will be announced shortly.

• **A revised list of essential activities to serve as a** guide for deferment from military service has been issued by the Commerce Department. It will help determine draft deferments and the calling up of National Guardsmen and reservists. Those mining and milling the following ores are considered to be in a "critical occupation": Aluminum, antimony, asbestos, beryllium, bismuth, borates, bromine, cadmium, cerium, chromium, cobalt, columbium, copper, cryolite, fluorspar, graphite, grinding pebbles, iron, kyanite, lead, lithium, magnesite, magnesium, manganese, mercury, mica, molybdenum, monozite, nickel, phosphate rock, platinum, potash, sodium, strontium, sulphur, tantalum, tin, titanium, tungsten, zinc, and coal.

• **At the Canadian Institute Meeting, Apr. 9 to 11** at Quebec City, it was evident that the Canadian mining industry is headed for a period of expansion. Canadian iron ore is now in great demand with the result that many new properties are being opened and existing mines are expanding production. Wabana, a producer for 50 years, is increasing production from 1,680,000 tons annual capacity to 2,800,000 net tons. Mechanization improvements include the use of trackless drill jumbos and loaders. A 12,000-ft slope belt conveyor is to be installed. Plans for the financing and development of Labrador iron ore are formulated. At the annual dinner of the CIMM, George M. Humphrey, president of The M. A. Hanna Co., emphasized that the Labrador project was not waiting for the St. Lawrence seaway but he stressed that the seaway was essential to the security of both nations. In 1950, the first ilmenite ore was shipped from Allard lake to Sorel for electric smelting to recover iron and titania. Steep Rock and Michipicoten areas are contributing substantially to the iron ore production of Canada.

In the nonmetallics field an important discovery of vermiculite was made in the Perth, Ont., area. This mineral is expanded in furnaces for use as insulation in buildings and as aggregate in lightweight heat and sound insulating, fire-resistant concrete, plaster and wallboard.

Probably the most outstanding pioneer achievement to be disclosed by any company is Hollinger's integrated industrial relations program. T. E. Hawkins of that company told how the program, which has been in force for 6 years, has reduced labor cost by over $1 million annually as a directly measurable consequence of the program. Each individual at the property from the manager down recognizes that the company is primarily interested in production but that this can best be achieved if each feels that this objective is in his own best interest. There are no rules at Hollinger. The lowest supervisor in charge of a group of miners is a part of management and it is his job to maintain two-way communication between his men and management. Employees are conversant with the policies and plans of the company. Proof of the effectiveness of the program is that employees remain with the company although higher wages may be obtained at some near-by mines.



# SULPHUR

by WILLIAM L. SWAGER
and
JOHN D. SULLIVAN

*This is the second in Mining Engineering's series of articles on sources, uses, production, and conservation of strategic minerals. "Cobalt", first in the series, appeared in February 1951.*

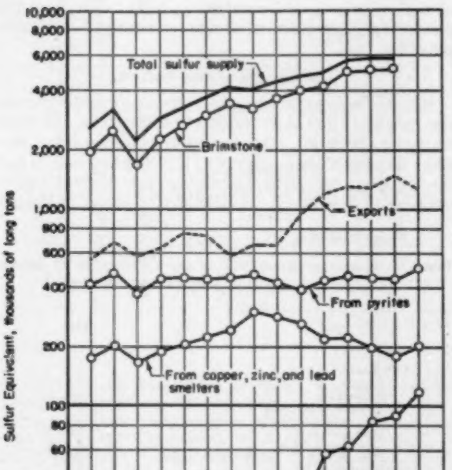



Fig. 1—Supplies of sulphur in the United States, 1936 to 1950, by source. (Source: "Chemical Engineering")

At about the turn of the century, the Frasch process revolutionized the sulphur industry. Sulphur from the Gulf Coast mined by this process soon became the dominant source in the United States and the world. But it appears that deposits amenable to the Frasch process can no longer provide the United States with sufficient sulphur for the ever-increasing wants of industry. It is time, then, to examine the uses and probable future supplies of sulphur in all forms, except natural sulphates, such as gypsum. Although natural sulphates[1] someday may supply a portion of the sulphur values now supplied by brimstone, pyrites, and hydrogen sulphide, it is unlikely that such will be the case in the next 5 or 10 years.

From the early 1900's, sulphur from the Frasch process increased in importance rapidly,[2] while pyrites and by-product acid from smelters became relatively less important sources—a trend that persisted through last year. The latter portion of this trend can be seen in Fig. 1, which shows the annual supplies of sulphur in the United States from 1936 to 1950. Exports have also been plotted for comparison. It will be noted that brimstone represents from 5 to 10 times the amount of sulphur that has been obtained from the next largest source, pyrites, including both domestic and imported. In the last 15 years, brimstone obtained by the Frasch process jumped from a production rate of about 2 million long tons annually in 1936 to almost 5 million tons in 1950. There has been no major change in the

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## Table I. Estimated End-Use Patterns For Sulphur From All Sources, 1936 to 1950[a]

| | Equivalent Sulphur From All Sources (Except Natural Sulphates), Thousands of Long Tons | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Acid Uses** | 1936 | 1937 | 1938 | 1939 | 1940 | 1941 | 1942 | 1943 | 1944 | 1945 | 1946 | 1947 | 1948 | 1949 | 1950 |
| Fertilizers | 385 | 432 | 368 | 437 | 437 | 482 | 567 | 775 | 818 | 883 | 936 | 1065 | 1080 | 1200 | 1224 |
| Chemicals[b] | 186 | 201 | 156 | 215 | 218 | 345 | 434 | 708 | 752 | 688 | 546 | 623 | 656 | 644 | 819 |
| Petroleum refining | 217 | 217 | 217 | 250 | 245 | 272 | 320 | 294 | 316 | 316 | 310 | 366 | 382 | 425 | 466 |
| Paint and pigments | 87 | 103 | 83 | 111 | 113 | 136 | 147 | 155 | 159 | 163 | 172 | 208 | 211 | 243 | 305 |
| Coal products | 151 | 169 | 114 | 176 | 175 | 183 | 188 | 181 | 195 | 188 | 159 | 218 | 206 | 170 | 191 |
| Rayon and films | 64 | 74 | 62 | 91 | 90 | 108 | 121 | 130 | 140 | 155 | 174 | 191 | 198 | 205 | 237 |
| Iron and steel | 151 | 217 | 115 | 237 | 253 | 292 | 311 | 167 | 175 | 178 | 148 | 169 | 175 | 155 | 192 |
| Other metals | 109 | 122 | 68 | 125 | 124 | 155 | 163 | 113 | 109 | 103 | 87 | 98 | 90 | 101 | 109 |
| Industrial explosives[b] | 43 | 35 | 28 | 34 | 33 | 33 | 37 | 36 | 37 | 31 | 33 | 39 | 40 | 38 | 41 |
| Textiles | 21 | 22 | 18 | 25 | 24 | 32 | 28 | 27 | 23 | 22 | 23 | 23 | 22 | 23 | 26 |
| Miscellaneous | 74 | 87 | 69 | 87 | 69 | 96 | 103 | 109 | 109 | 125 | 99 | 115 | 116 | 117 | 121 |
| Acid subtotal | 1488 | 1679 | 1298 | 1788 | 1781 | 2134 | 2419 | 2695 | 2833 | 2852 | 2687 | 3115 | 3187 | 3321 | 3731 |
| **Non-Acid Uses** | | | | | | | | | | | | | | | |
| Pulp and paper | 260 | 302 | 174 | 240 | 320 | 360 | 365 | 305 | 300 | 297 | 305 | 370 | 380 | 330 | 425 |
| Industrial explosives | 10 | 33 | 22 | 30 | 41 | 50 | 53 | 54 | 51 | 59 | 57 | 61 | 70 | 60 | 60 |
| Rubber | 39 | 37 | 29 | 43 | 47 | 55 | 35 | 45 | 55 | 58 | 65 | 65 | 63 | 58 | 65 |
| Chemical and miscellaneous | 204 | 192 | 125 | 199 | 202 | 240 | 304 | 442 | 364 | 366 | 403 | 414 | 544 | 536 | 460 |
| Non-acid subtotal | 513 | 564 | 350 | 512 | 610 | 705 | 757 | 846 | 770 | 780 | 830 | 910 | 1057 | 984 | 1010 |
| **TOTAL** | 2001 | 2243 | 1648 | 2300 | 2391 | 2839 | 3176 | 3541 | 3603 | 3632 | 3517 | 4025 | 4244 | 4305 | 4741 |

[a] Calculated from estimates made by *Chemical Engineering*.
[b] Direct military consumption included in the chemical classification.

amount of sulphur equivalent recovered from pyrites burned in the United States in the last 15 years, the average production in this period running about 450,000 long tons of sulphur equivalent annually. Prior to and during World War II, sulphur values obtained from copper, zinc, and lead smelters rose markedly from a level of less than 200,000 long tons of sulphur equivalent in 1936 to nearly 300,000 tons in 1943. But since that time the recovery of sulphur values from metal smelters has fallen to about the 1936 level.

Although sulphur values recovered from natural gas, petroleum refinery gases, and other industrial gases represent a small proportion of the total supply, the trend indicated by Fig. 1 is worthy of note. Data are unavailable for production-of-sulphur values from these gases prior to 1939. At that time, about 16,000 long tons of sulphur equivalent were produced. Today sulphur from this source probably amounts to about 150,000 long tons annually.

### End-Use Patterns

For several years, *Chemical Engineering* has estimated annually the end-use patterns for crude sulphur and sulphuric acid. These estimates were used as a basis for Table I, which gives estimated end-use patterns for sulphur from all sources, from 1936 to 1950, in terms of equivalent sulphur. Consumption is broken down into two major classifications, acid uses and non-acid uses. In calculating the data under acid uses, it was assumed that the acid was produced with an average over-all yield of 94 pct, based on sulphur.[4] In order to eliminate some of the variables that are associated with the general upward trend in population, the data given in Table I were recalculated on a per capita basis. These data have been plotted and are shown in Fig. 2. Referring to Table I and Fig. 2, it is apparent that the consumption of sulphur as sulphuric acid in fertilizers and in the production of chemicals has jumped 300 to 400 pct within the past 15 years. Why is sulphur short? Where is it all going? Most of the answers can be found here. The consumption of sulphur in petroleum, coal products, paints and pigments, rayon and films, and rubber has increased only moderately, but sizable quantities of sulphur have been exported in recent years. Fig. 1 shows that even in 1936 exports amounted to much more than the amount of sulphur recovered from pyrites annually. From 1936 to 1943, exports amounted to more than the total amount of sulphur values recovered from pyrites, copper, zinc, and lead smelters, and industrial and natural gases.

Table II indicates the relative importance of each of the various uses for sulphur. This table gives the percentage breakdown of the consumption of sulphur for 1949.

### The Changing Use Pattern

Several economic pressures are tending to change the present end-use pattern. Exports have been traditionally high, and worldwide demand for sulphur has been rising rapidly. Cutting exports is not the answer, for with increasing government intervention it is difficult to predict the level of future

**Table II. Percentage Breakdown of the Consumption of Sulphur From All Sources Except Natural Sulphates, 1949**

| Use | Pct |
|---|---|
| **Acid Uses** | |
| Fertilizers | 27.9 |
| Chemicals | 15.0 |
| Petroleum refining | 9.9 |
| Paint and pigments | 5.6 |
| Coal products | 3.9 |
| Rayon and films | 4.8 |
| Iron and steel | 3.6 |
| Other metals | 2.4 |
| Industrial explosives | 0.9 |
| Textiles | 0.5 |
| Miscellaneous | 2.7 |
| Acid subtotal | 77.2 |
| **Non-Acid Uses** | |
| Pulp and paper | 7.7 |
| Industrial explosives | 1.4 |
| Rubber | 1.3 |
| Chemical and miscellaneous | 12.4 |
| Non-acid subtotal | 22.8 |
| **TOTAL** | 100.0 |

exports and it is likely that the pressures from abroad, particularly through ECA, will force exports to continue at a relatively high level.

In the past the consumption of brimstone has followed closely the Federal Reserve Board index of industrial production (Fig. 3). During the war, the index rose out of proportion for several years, but in the postwar period, it again nearly paralleled the consumption of brimstone. Since the consumption of sulphur is so sensitive to fluctuations in general business activity, it must be assumed that general business activity will rise at least in proportion to the population increase.

The fertilizer industry now consumes the largest percentage of total sulphur production. Most of the sulphuric acid used in the fertilizer industry is consumed in the manufacture of superphosphates. The process is a simple one involving the treatment of raw phosphate rock with about 50° to 55° Bé sulphuric acid. About 650 lb of 100 pct sulphuric acid is required per ton of superphosphate. After a prolonged storage period, the superphosphate is usually mixed with other fertilizer ingredients and sold as mixed fertilizer. In recent years, there has been a trend toward the production of a higher strength product, triple superphosphate. This is manufactured from phosphoric acid and phosphate rock, but the most common method for producing phosphoric acid for fertilizers involves sulphuric acid. Roughly the same amount of sulphuric acid is required in the manufacture of triple superphosphate and superphosphate on an available-$P_2O_5$ basis. Phosphoric acid can also be produced by the oxidation of elemental phosphorus. Bell and Waggaman[5-7] made an exhaustive study of the costs of producing triple superphosphate using alternative methods for producing the intermediate phosphoric acid. On the basis of their work, done in 1946 and 1947, the cost of phosphoric acid, calculated as $P_2O_5$, produced from sulphuric acid was $57.28 per ton. Phosphoric acid on the same basis, produced by the electric furnace process, costs $73.74 per ton. The cost of sulphuric acid used in this estimate was $6.50 per short ton of 100 pct acid. The cost of power used was estimated to be 2.5 mills per kw-hr. The cost of triple superphosphate expressed in terms of $P_2O_5$ was estimated to be slightly over $50 per ton for the sulphuric acid process and somewhat over $60 per ton for the electric furnace process. From the detailed cost breakdown given by Waggaman and Bell, the cost of sulphuric acid would have to nearly double before the two processes would produce acid at the same cost—other factors remaining equal.

There are other methods for manufacturing phosphate fertilizers that do not require sulphuric acid.[8] Hill breaks the possible treatments down into two groups. First, phosphate rock can be treated with hydrochloric acid, or nitric acid, as well as sulphuric and phosphoric acids, previously mentioned. Either of these treatments will produce a satisfactory phos-

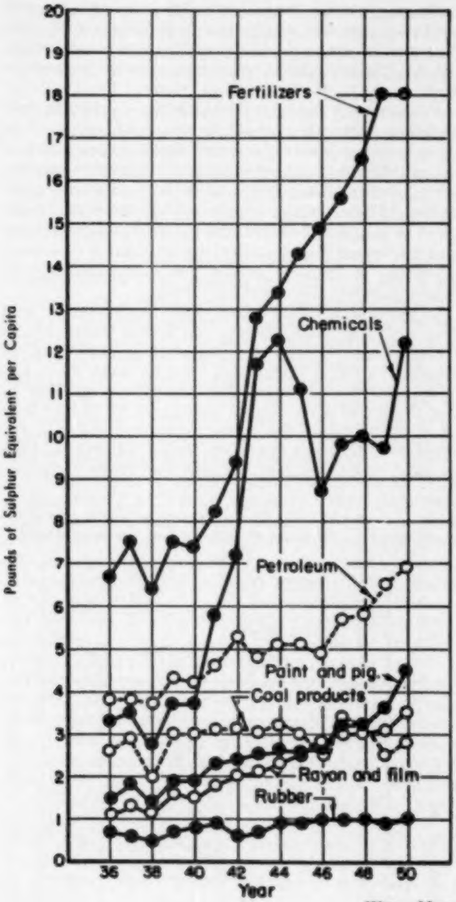



Fig. 2—Per capita consumption in the United States, 1936 to 1950, of sulphur used in major industrial applications. The sharp (300 to 400 pct) increase in sulphur consumption in fertilizer and chemical production is clearly portrayed here.

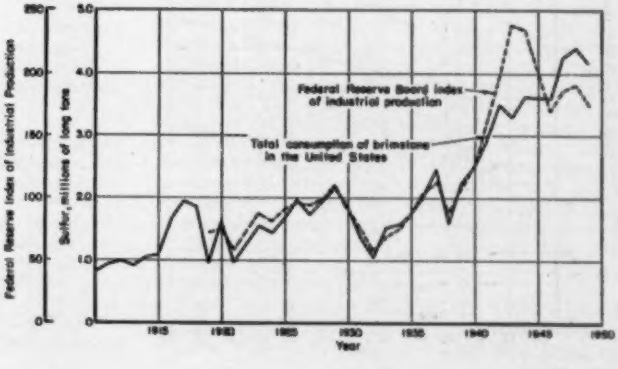



Fig. 3—Brimstone consumption has followed closely the movements of the Federal Reserve Board Index of Industrial Production.

phate fertilizer. The second main classification is thermaldefluorinization. This can be accomplished by either fusion or calcination. A commercial plant in Tennessee was run for some time on this process. These methods are technically feasible, but relatively expensive.

Thus there are a number of ways to produce phosphate fertilizer materials without using sulphuric acid, but probably they won't be in general use for some time, because it is cheaper to make superphosphate or triple superphosphate using sulphuric acid. Because of agricultural trends, including the desire to shorten the growing period to avoid frosts, it appears that sulphuric acid will be required in increasing amounts for the production of fertilizers.

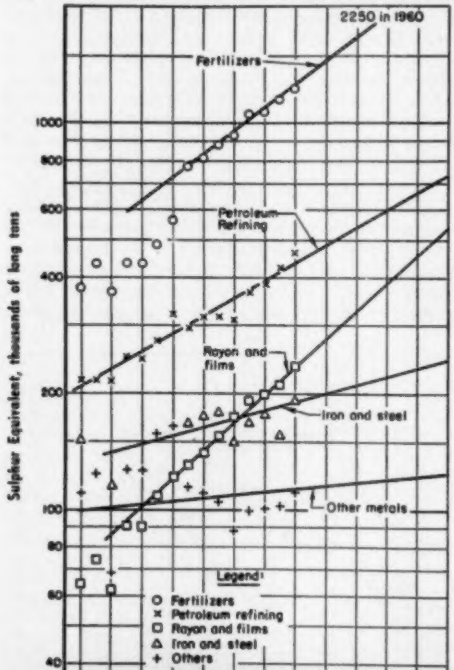
*Chemical Engineering* made an extrapolation into the future for several of the chemical process industries.[a] It was indicated that the fertilizer industry may rise from an index level of about 260 in 1950 to an index level of 380 by 1960. This does not take into consideration the demands fostered by the present world situation. If on the other hand, an extrapolation is made to 1960 of the current trend in the consumption of sulphur in the fertilizer industry, a much higher demand is indicated, equivalent to an index level of nearly 480. If such an increase becomes a reality, it means that the use of sulphuric acid in the manufacture of fertilizers may nearly double.

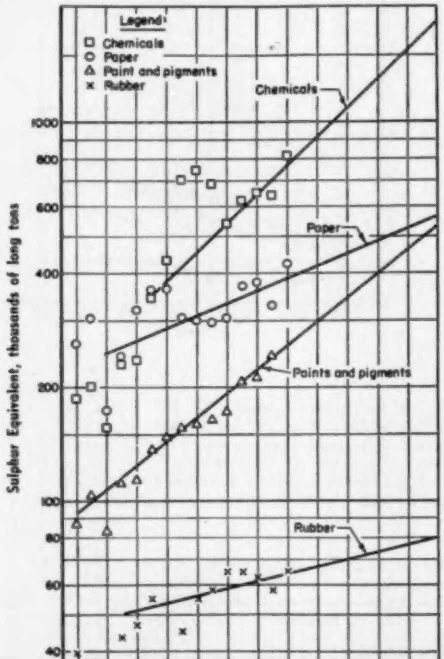
It is difficult to attribute to specific products all of the increased demand for sulphuric acid in the chemical industry, but several segments of the industry account for a large portion of the increase. There has been a rapid increase in the production and use of detergents, many of which are sulphonated products. Many organic syntheses require sulphuric acid as a dehydrating agent. The sharp rise in the production of organic chemicals has accounted for much of the sulphuric acid required in the chemical industry. *Chemical Engineering* indicates that if recent trends are maintained the chemical industry will rise to an index level of 900 by 1960 from the current level of about 420. The use of sulphuric acid probably will follow the same index, indicating that the chemical industry will require more than twice as much sulphuric acid in 1960 as it does today.

The postwar demand for petroleum products surprised nearly every expert in the business, and the growth curve hasn't slackened much in the last few years. *Chemical Engineering* estimates that the petroleum industry will rise to a production level indicated by an index number of 330 from its present level of about 215. Increases in refinery throughput and increased use of alkylate will force the consumption of sulphur in the petroleum industry to follow roughly the trend indicated.

In general, the other uses indicated in Table I and Fig. 1 will probably follow the trends generated in recent years. There are no radical technological changes in being that would tend to make the usage of sulphur deviate from these trends. A number of the *Chemical Engineering* estimates of "what may be in 1960" have been superimposed on plots of the sulphur values consumed in major industries, 1936 to 1950, found in Figs. 4a and 4b. Only estimates

**Figs. 4a, 4b—Plot of sulphur values consumed by major industries, 1936 to 1950, projected to 1960. This big demand for sulphur, plus shortages and price increases, will stimulate exploitation of marginal sources and encourage the saving of sulphur values now being wasted.**



for the following industries were used from those made by *Chemical Engineering:* Chemicals, petroleum, paper, synthetic fibers, and rubber products. For industries not covered by *Chemical Engineering* estimates but including fertilizers, extrapolations were made of the 1936 to 1950 data on the consumption of sulphur. This cannot be called an estimation of the consumption of sulphur in 1960 but rather an economic driving force, that is indicated by trends in the consuming industries. It is true that this could be considered an estimate of the consumption of sulphur in 1960 if there were no restrictions on the supply, but sulphur available today is insufficient to meet the demand. But the unprecedented demand for sulphur, plus the recent increase in the price of crude sulphur at the mine, is likely to cause two things: first, previously submarginal sources of supply will be exploited, increasing the supply, and second, consumers of sulphur will look for processes to conserve or re-use presently wasted sulphur values, decreasing the demand.

### Future Supplies of Sulphur

It should be kept in mind that 85 to 90 pct of the sulphur consumed is used in the oxidized form. That is to say, sulphur dioxide and sulphuric acid are the important chemicals from a usage standpoint. Elemental sulphur is the most convenient form for shipping, for 1 ton of sulphur is equivalent to 2 tons of $SO_2$ and nearly 3.3 tons of 66° Bé acid. A potential supplier of sulphur values will consider production of elemental sulphur only if his producing location is remote from consuming centers.

Production of crude sulphur from the Gulf Coast area is now at a peak. It is probable that production from this area will remain steady at this level for a number of years, but that it is unlikely that there will be a substantial increase in production—barring a rapid jump in the price of crude sulphur which would make economical the working of small dome deposits, and also barring large discoveries in Mexico and in exploratory work being done on the Continental Shelf off the Gulf Coast.

The recent announcement by the Chemical Construction Co. of a new process for recovery of sulphur from low-grade surface deposits warrants mention. It has been alleged that the process can produce relatively pure sulphur from ores containing 30 pct of sulphur at a cost of from $15 to $18 per long ton. The reserves of low-grade sulphur deposits in the Western States were estimated to be 2 million long tons.[20] Assuming that such a reserve estimate is conservative, it appears that recovery of sulphur from low-grade ores in the United States will help in a small way to increase domestic supplies. Use of this process abroad may serve to reduce foreign demand for Gulf Coast sulphur.

Any substantial increase in the supply of sulphur will therefore have to come from by-product sources.

### By-Product Acid

The production of by-product sulphuric acid from copper, zinc, and lead smelters has long been an important source of sulphur values, but only a small fraction of the potential is now being recovered. If the potential is defined as the amount of sulphur contained in the concentrates consumed in the copper, zinc, and lead industry, we can estimate the potential as follows: for every pound of copper produced in the country, there is associated with it in the concentrates about 1 lb of sulphur. For every pound of zinc produced in the country there is about ½ lb of sulphur associated with it in the concentrates. Lead concentrates run about 15 pct sulphur or about 0.17 lb of sulphur for every pound of lead. Using these factors, it is estimated that the total amount of sulphur entering copper smelters today is about 800,000 long tons of contained sulphur, that being processed in zinc smelters amounts to about 390,000 long tons, and that being processed in lead smelters amounts to about 60,000 long tons, making the potential from smelters about 1,250,000 long tons of contained sulphur. Because of the variation in the practices among the various smelters, it is difficult to estimate the amount of this potential that might be recovered by current technological processes.[21]

In copper operations, by proper changes in roaster and converter design, particularly to prevent dilution by air, it is assumed that it will be possible to secure gases high enough in $SO_2$ concentration to produce an estimated 500,000 to 600,000 long tons of sulphur equivalent annually. But there has been a tendency in recent years to eliminate roasters and to produce matte from green concentrates. The gas from such operations is probably too lean for the manufacture of sulphuric acid, and hence the above estimate may be considered rather optimistic. However, it is technically feasible to remove $SO_2$ from gases having $SO_2$ concentrations as low as 1 pct, and the general application of such processes would mean the recovery of an even larger portion of the sulphur potential from smelters.

Based on the ratio of the zinc concentrates presently consumed in plants making by-product acid to the amount of sulphuric acid produced, it has been estimated that 370,000 long tons of equivalent could be recovered from the 390,000 long tons potentially available. About half of the potential amount of sulphur in lead concentrates would come from a lead smelter in gases of sufficient concentration to make sulphuric acid—a probable recovery of about 30,000 long tons equivalent sulphur. By totaling the above, it is estimated that between 900,000 to 1 million long tons of equivalent sulphur might be recovered from metal smelters as by-product acid. This assumes that there will be a ready market in the immediate vicinity of each of the individual smelters. In actuality, such is not the case.

### Hydrogen Sulphide Recovery

There are various methods for the removal of hydrogen sulphide from sour natural gases and industrial gases.[22-26] If all of the sulphur could be removed during refining, how much sulphur might be made available as a by-product of petroleum refineries? Smith and Blade[27-29] have made a comprehensive study of the sulphur content of crude oils. Based on these data, it is estimated that there is the equivalent of 2 to 3 million long tons of sulphur entering the petroleum refineries of the United States each year. But only 10 to 20 pct is converted to hydrogen sulphide during the refining process, the remainder passes through into the products.[30] Only about half of the hydrogen-sulphide-containing gases are produced in refineries of sufficient size to make recovery of the hydrogen sulphide economical. It is estimated that about 150,000 to 300,000 long tons of equivalent sulphur could be recovered from the hydrogen sulphide off-gases of the larger petroleum refineries in the United States.

There are several places in the United States where natural gas contains sizable percentages of hydrogen sulphide.[30-33] Based on the data given by

Weber, Espach, and Cunningham, it has been estimated that there is a potential of about 300,000 long tons of sulphur equivalent in sour natural gases. Of this potential, a minor portion is extracted in small natural gasoline or natural gas operations, and therefore probably is not economical to recover. The amount that may be recovered from the larger operations is estimated to be about 230,000 long tons of equivalent sulphur.

It is unlikely that large quantities of sulphur will be recovered profitably from other industrial gases for, in general, the concentration of sulphur values is low. It is more likely that sulphur will be removed from stack gases to reduce air pollution. Large thermal electric generating plants burning high-sulphur coal would probably be the first of the industrial plants to recover sulphur from stack gases. Because of the large number and varied types of these and other industrial gases, no attempt has been made to estimate the potential amount of sulphur now being wasted to the atmosphere. Estimates made by Katz and Cole, however, indicate the order of magnitude of such waste.[20]

### Pyrites

Pyrites form the largest potential source of additional sulphur. For the purpose of estimating the amount of pyrites that might bolster the supply of sulphur in this country, it is convenient to classify the possible pyrites sources in four categories. First, there are large quantities of pyrites presently mined but considered gangue in other ores. These sulphur values are either depressed or sent to the tailing pile during normal concentrating operations. The second classification includes those pyrites orebodies that are in present mines, but which have been left in the walls, roofs, and pillars. Third, there are independent pyrites orebodies that would have to be mined for the sulphur values alone. There are also large quantities of pyritic sulphur in the coals being mined in certain parts of the United States, including Ohio, Kentucky, Indiana, Illinois, and Kansas.

By proper treatment of pyrite and marcasite, it is possible to recover perhaps as much as 35 pct of the sulphur in the elemental form, the remainder being recovered as $SO_2$. By-product $Fe_2O_3$ is increasing in value, as well as the sulphur constituents. Undoubtedly these economic factors will bring on the market increasing quantities of sulphur in one form or another.

It is estimated that, for every ton of equivalent sulphur in concentrates of sulphide ores, there is associated with it about an equivalent amount of sulphur as pyrites, most of which is currently discarded. On this basis, it was estimated that there is a potential of about 1,300,000 long tons of equivalent sulphur currently being mined. It is estimated that about 1 million tons per year of this potential might be recoverable.

No attempt has been made to estimate the amount that might be brought on to the market annually from pyrites orebodies in present mines and from independent pyrites orebodies. The reserves of pyrites are substantial.[21] As reported in the public press, Noranda Mines, Ltd. will process more than 100 tons of pyrites per day in a new plant in Ontario, producing elemental sulphur, sulphuric acid, and iron sinter. Undoubtedly a continuing sulphur shortage and higher prices would bring some of this type of material on the domestic market.

Prior to World War II, imports of pyrites contained about 200,000 long tons of equivalent sulphur. It is likely that pyrites shipments from Spain will come back up to the prewar level. Potentially, large quantities of pyrites and by-product acid are available in Canada. It has been estimated that over 1 million long tons of sulphur equivalent are wasted by metal smelters in the Sudbury area alone. In addition, large quantities of pyrites are associated with these ores, which are removed during concentration. A continuing sulphur scarcity and higher prices for sulphur values will probably bring a portion of this potential on to the market.

Wells and Fogg[22] estimated that about 1,500,000 short tons of coal brasses might be recovered from high-sulphur coals at the 1920 production level. The sulphur content of the brasses is about 45 pct. If recovered it would have amounted to about 600,000 long tons of equivalent sulphur based on 1920 production levels. Since coal production in these areas is down about 20 pct, it is conservatively estimated that about 500,000 long tons of equivalent sulphur might be recovered from coal brasses.

Even excluding two of the classifications for pyrites it is probable that about 1,700,000 long tons of equivalent sulphur might be recoverable from the potential of 3,800,000 long tons.

The supply situation is summarized in Table III. About 3 million long tons might be recovered from the potential of between 7 and 8 million long tons

**Table III. Potential Sources of Sulphur Values in the United States Excluding Brimstone**

| Sources | Potential[a] (Long Tons of S) | Recoverable[b] (Long Tons of S) | Approx. Annual Capacity of Present Recovery Plants |
|---|---|---|---|
| By-product acid from smelters | | | |
| Copper | 800,000 | 500,000 to 600,000 | |
| Zinc | 390,000 | 370,000 | |
| Lead | 60,000 | 30,000 | |
| Subtotal | 1,250,000 | 900,000 to 1,000,000 | 200,000 |
| By-product from natural and industrial gases[c] | | | |
| Petroleum refining | 2,000,000 to 3,000,000 | 150,000 to 300,000 | 110,000 |
| Sour natural gas | 300,000 | 230,000 | 120,000 |
| Subtotal | 2,300,000 to 3,300,000 | 380,000 to 530,000 | 230,000 |
| Pyrites | | | |
| Pyrites presently mined, but considered gangue in other ores | 1,300,000 | 1,000,000 | 220,000 |
| Pyrites orebodies in present mines which have been left in walls, etc. | [d] | [d] | |
| Independent pyrites orebodies | [d] | [d] | 150,000 |
| Coal brasses | 2,500,000 | 500,000 | None |
| Imports | —— | 200,000[e] | 60,000 |
| Subtotal | 3,800,000 | 1,700,000 | 430,000 |
| GRAND TOTAL | 7,350,000 to 8,350,000 | 2,980,000 to 3,230,000 | 860,000 |

[a] Potential means the amount of sulphur that could be made available annually if all of the sulphur values contained in the raw materials could be recovered.

[b] Recoverable refers to that portion of the potential that could be removed economically by present technological processes if there was a market for the sulphur values in the immediate vicinity of the recovery plant.

[c] Excludes the possible recovery of large amounts of sulphur values from stack gases of power and other industrial plants burning high-sulphur coal.

[d] Data are unavailable on which to base an estimate. Undoubtedly, a sulphur shortage and higher sulphur prices would bring some of this material into the market.

[e] The level of imports pre-World War II.

of equivalent sulphur. Less than one-third of the technologically recoverable sulphur is now used, not including certain types of pyrites deposits, possible recovery of sulphur dioxide from anhydrite, low-grade native sulphur deposits such as those found in western Texas,[26] Wyoming, Utah, California, and New Mexico, nor elemental sulphur production from presently submarginal small dome deposits which might be realized at higher price levels.

### Increasing Costs May Shift Demands

The question remains as to how much and at what price these sulphur values will be brought on the market. Since the economics of these by-product and pyrites operations depend so much upon local conditions, it is virtually impossible to generalize on the subject. Much sulphur could be made available at higher prices. But consumers will inquire critically of the amount of sulphur currently being lost in one way or another. An acid plant designed to burn pyrites costs about 1.75 times that for a plant burning brimstone and operating costs are about 1.7 times those of a plant burning brimstone. Cost of new acid may be greater than the costs of recovering that presently wasted. Higher prices for crude sulphur will bring about the same relation between new and recovered sulphur in industries using elemental sulphur or its non-acid derivatives. For instance, in the rayon industry losses of carbon disulphide run high. In the past, it has been cheaper to replace with new carbon disulphide rather than take measures needed to reduce the losses. It is alleged that the consumption of carbon disulphide in the rayon industry could be reduced to nearly half of its present level if available recovery systems were adopted. Also, in many industries it has been the practice to pass to the sewer diluted and spent acids. Recent interest in pickle-liquor recovery in the steel industry indicates that the practices wasteful of sulphur values are being re-evaluated and the conservation steps are being taken. It must be admitted that in the past the major impetus for such measures has not come about through conservation efforts, but rather through government demands to reduce stream and air pollution. Regardless of whether the pressure is from one direction or another, the end result will be conservation of sulphur values.

To put all of the data into a composite picture, it all adds up to this. There is plenty of sulphur available but not at the price that is currently being paid for brimstone. The economic driving force indicated by the estimated demand for sulphur in 1960 will gradually bring on to the market increasing quantities of by-product sulphur values at increasing prices. The marginal sources, of course, will always demand a premium price. With increasing costs for sulphur values, consumers will be looking for methods to reduce their intake of sulphur. Just where the supply-cost-demand level will reach equilibrium is anyone's guess. In any event, there appears to be no long-term sulphur shortage and no revolution in the industry that will have severe repercussions. It will be a gradual struggle between the suppliers and the consumers in the market place.

## References


[1] Sulphuric Acid from Anhydrite. *Industrial Chemist*, pp. 390-394, September 1950.

[2] William Haynes: *The Stone That Burns*, D. Van Nostrand, Co., Inc., 1942.

[3] W. L. Faith, D. B. Keyes, and R. L. Clark: *Industrial Chemicals*, John Wiley & Sons, Inc., pp. 595-603, 1950.

[4] R. E. Bell and W. H. Waggaman: Western Phosphates—Potential Markets, *Industrial and Engineering Chemistry*, Vol. 42, No. 2, pp. 286-292, Feb. 1950.

[5] W. H. Waggaman and R. E. Bell: Western Phosphates—Factors Affecting Development, *Industrial and Engineering Chemistry*, Vol. 42, No. 2, pp. 269-276.

[6] W. H. Waggaman and R. E. Bell: Comparison of Sulphuric Acid and Thermal-Reduction Processing, *Industrial and Engineering Chemistry*, Vol. 42, No. 2, pp. 276-285.

[7] W. L. Hill: Phosphate Fertilizers—Their Manufacture From Phosphate Rock Without Use of Sulphuric Acid, *Agricultural Chemicals*, Vol. V, No. 12, pp. 55, 86-86B, Dec. 1950.

[8] Editorial Staff, *Chemical Engineering*, Vol. 57, No. 11, pp. 158-159, Nov. 1950.

[9] *Mineral Position of the United States*, United States Geological Survey, 1947.

[10] E. P. Fleming and T. C. Fitt: Liquid Sulphur Dioxide From Waste Smelter Gases, *Industrial and Engineering Chemistry*, Vol. 42, No. 11, pp. 2253-2258, Nov. 1950.

[11] F. G. Sawyer, R. N. Hader, K. L. Herndon, and E. Morningstar: Sulphur From Sour Gases. *Industrial and Engineering Chemistry*, Vol. 42, No. 10, pp. 1938-1951, Oct. 1950.

[12] A. E. Sands and L. D. Schmidt: Recovery of Sulphur From Synthesis Gas. *Industrial and Engineering Chemistry*, Vol. 42, No. 11, pp. 2277-2287, Nov. 1950.

[13] R. M. Reed, N. C. Updegraff, and J. L. Parker: Removal of Hydrogen Sulphide From Industrial Gases. *Oil and Gas Journal*, Vol. 49, No. 35, pp. 48, 51-52, 58, 61, Jan. 4, 1951.

[14] R. A. Graff: Elemental Sulphur From Petroleum Gases. *Oil and Gas Journal*, Vol. 47, No. 42, pp. 99, 103, 104, Feb. 17, 1949.

[15] G. Weber: Sulphur From Sour Gas. *Oil and Gas Journal*, Vol. 45, No. 44, pp. 58-59, 84-87, Mar. 8, 1947.

[16] H. M. Smith and O. C. Blade: High Sulphur Crude Oils of the United States—Trends in Supply. *Proceedings*, the American Petroleum Institute, Vol. 27, No. III, pp. 119-140, 1947.

[17] O. C. Blade: Additional Data on Sulphur in Crude Oil. *Oil and Gas Journal*, Vol. 47, No. 42, p. 95, Mar. 31, 1949.

[18] M. J. Fowle and R. D. Bent: Where Does Sulphur Go? *Proceedings*, the American Petroleum Institute, Vol. 27, No. III, p. 141, 1947.

[19] W. A. Cunningham: Hydrogen Sulphide in West Texas. *Industrial and Engineering Chemistry*, Vol. 42, No. 11, pp. 2238-2241, Nov. 1950.

[20] R. H. Espach: Sources of Hydrogen Sulphide in Wyoming. *Industrial and Engineering Chemistry*, Vol. 42, No. 11, pp. 2235-2237, Nov. 1950.

[21] G. Weber: Sulphur From Sour Gas. *Oil and Gas Journal*, Vol. 45, No. 44, pp. 58-59, 84, 87, Mar. 8, 1947.

[22] M. Katz and R. J. Cole: Recovery of Sulphur Compounds From Atmosphere Contaminants. *Industrial and Engineering Chemistry*, Vol. 42, No. 11, pp. 2258-2269, Nov. 1950.

[23] *Mineral Position of the United States*. U. S. Bureau of Mines and U. S. Geological Survey, pp. 294-296, 1947.

[24] A. E. Wells and D. E. Fogg: Manufacture of Sulphuric Acid in the U. S., Bureau of Mines *Bulletin* 184, July 1920, pp. 51-54.

[25] Glen L. Evans: The Rustler Springs Sulphur Deposits as a Source of Fertilizer, *Report of Investigations*—No. 1, Bureau of Economic Geology, University of Texas, Sept. 1946.

# ORE FROM THE ORINOCO

A PROSPECTOR stood atop a Venezuelan mountain called El Florero just 25 years ago, and shouted to the world that he had found a large, rich new source of iron ore. But his words were lost in the big green South American jungles and besides, the world had more iron ore than it could handle. There were no crises in 1926, no major wars on the horizon, no worries about mineral supplies. In the U. S., the populace was "keeping cool with Coolidge," and the solid foundation of the economy—the steel industry—rested on a still firmer basis, the Lake Superior iron ores.

But the prospector's cry in the jungle portended the drumbeating heard twenty years later, when it became apparent that American iron ore could not support an infinite number of wars and threats of war—or even an ever-growing industrial potential. No one knew or cared, but the nameless prospector was, in 1926, solving one problem that was to confront the generation being born as he stood on El Florero.

In 1933 Bethlehem Steel bought more than 20,000 acres of the ore-bearing land around El Florero. It was a timely purchase, considering that Adolf Hitler took over Germany in the same year and began our current era of crises. Bethlehem waited 4 years before sending in surveyors, and still another 4 years before beginning construction work. The timetable was altered by World War II and 5 more unproductive years went by.

But this year El Florero ("the flower-girl") delivered her first bouquet to America's steelmakers—the first cargo of iron ore arrived at Bethlehem's Sparrows Point, Md., plant on March 22.

Bethlehem's operations site, El Pao, located near El Florero, consisted of a few huts in 1926 but is now a showplace of modern mining technology. The company has built a 30-mile, 2-lane highway between El Pao and the Orinoco River port of Palua. It has moved over 1½ million cu yd of earth in laying 38 miles of railroad track from Palua to the mine. It has brought in crushers, conveyors, power shovels, railroad cars, locomotives, trucks, docks, rails—in short, everything needed to run a large-scale mining enterprise. A river loading station and a deep water port were built, as well as a fleet of shallow-draft vessels, tugs, and barges. Three communities were created in the wilderness, and sev-

**At left, dumping ore into the primary crusher at the El Pao mine. At Puerto de Hierro (right), 270 miles from El Pao, the ore is taken from barges to await shipment to the U. S. Picture at top of page shows ore bridge at Palua under which 800,000 tons of ore can be stored.**

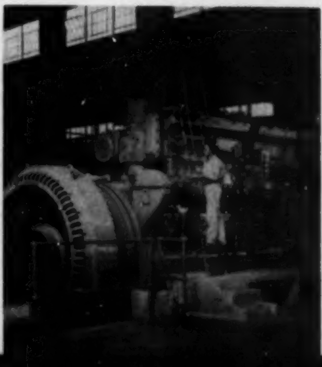

eral hundred miles of river were sounded, charted, and marked with navigation aids.

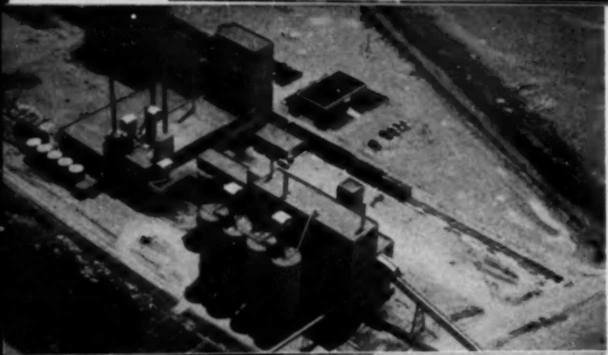
The hill being mined is sliced off in 13-meter high benches, with cat-mounted churn drills drilling the ore. A fleet of ten 30-ton trucks delivers the ore to the primary crusher. It proceeds to the secondaries on a conveyor belt, and is then hustled off, on another belt, to a 4000-ton storage bin located over the tracks at the rail head. Four times a day, 33-car trains loaded from the bin wend a slow, steep descent to Palua on the Orinoco.

At Palua the trains run over a high trestle, discharging their loads into an ore pocket capable of holding 44,000 tons of the high-grade hematite. When the barges are ready for loading at Palua, the ore is chuted from the bottom of the pocket onto a conveyor belt running inside a concrete tunnel. Emerging from the tunnel, the ore takes a sharp right turn and proceeds, on another belt, to a steel loading structure which cantilevers out over the Orinoco. Five 4500-ton barges receive the ore through a telescoping steel chute. This chute, and the floating dock at which the barges tie up, were necessary concessions to the Orinoco, which rises and falls, with the seasons, an amazing 43 ft!

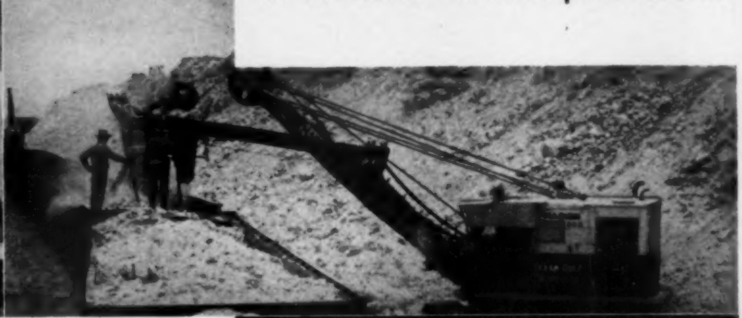
From Palua, the barges are pushed by 1300-hp tugs down the Cano Manamo, out into the Gulf of Paria, and across the gulf to Puerto de Hierro, Bethlehem's big new tidewater installation. Unloading towers pull the ore out of the barges in 8-ton grab buckets, and conveyors move it back to a huge storage pile to await transfer to ocean-going vessels. The hematite begins the last lap of its journey in a tunnel similar to the one at Palua, moving from it into the holds of 26,000-ton ore vessels. Thirteen days after leaving Puerto de Hierro, the big ships are back from Sparrows Point, hungrily awaiting another bellyful of ore.

**Map shows the railroad and barge route from El Pao to Puerto de Hierro, where the ore is transshipped to the U.S. River vessel route is for larger vessels. Pictures show shovel working at the mine, loading of cars from the ore bin at the rail head, and a trainload of ore enroute to Palua. Then, the train is seen high on the trestle over the ore pocket at Palua. Next picture shows the tunnel through which ore is taken out of the pocket, falling through chutes onto a 48-in. conveyor belt. Power at El Pao is supplied by three 980-kw Diesel-Electric generators of the type shown, as well as other units. The last picture is of comfortable staff houses at Puerto de Hierro.**





# Southwestern



the past decade has witnessed a

of industrial minerals produced in

by HAROLD B. FOXHALL

THIRTY per cent of the mineral wealth of the United States is obtained from seven states: Arkansas, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas. This area, which produced $4,727,156,000 worth of minerals in 1948, constitutes an almost complete economic unit in relation to mineral resources essential to industry. All of these states are producers of fuels and some of metallics, but in the field of important nonmetallic industrial minerals the picture is near perfection—a mineral any one of the seven states lacks, one of the others has in quantity.

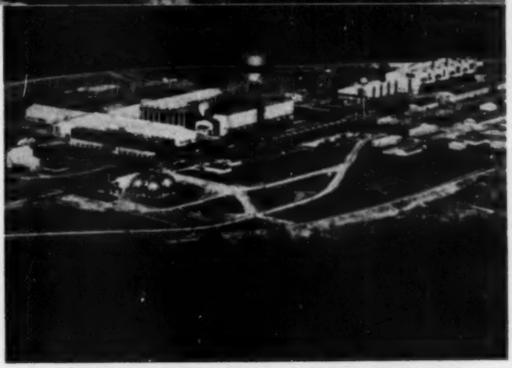
In the last 10 years the total value of industrial minerals produced in the Southwest has risen almost 300 pct. This wave of industrialization which began in the late thirties was given enormous impetus by World War II.

There has been no significant postwar retrenchment as was predicted by many, but instead an accelerated continued expansion of the industrial mineral industry. The most significant trend has been that the expansion in the industrial mineral field has been in the nature of processing industries—manufacturing to the finished product within the state where the natural resource is mined—not the depletion and extractive policy so prevalent in the past. Most fortunate of all is that these industries were not temporary war plants, but permanent, well-engineered, well-financed operations.

The expansion has not been confined to minerals. Significantly, the growth of the chemical industry in the Southwest, particularly in Texas and Louisiana, has established a "local" demand and market for other mineral resources.

Construction materials such as cement, sand and gravel, stone, clay products, and gypsum all showed an increase from 1939 to 1942 followed by a decrease to a low in 1944, when building restrictions were most severe. A steady increase in tonnage and value has followed World War II.

MR. FOXHALL is Director, Division of Geology, Arkansas Resources and Development Commission, Little Rock, Ark.



At top of page is Minnesota Mining & Mfg. Co. roofing granule plant at Little Rock, Ark. Below it are shown water softeners at the New Gulf Plant of Texas Gulf Sulphur, and sulphur being loaded on railroad cars at New Gulf. At bottom is the Lion Oil Co.'s chemical plant at El Dorado, Ark., where ammonium nitrate used in fertilizers is manufactured.

Other minerals such as bauxite, barite, salt, sulphur, and lime showed rising production during the war. In the case of bauxite, the maximum production was reached in 1943 when war shipping became so critical as to seriously curtail imports.

### Construction Materials

**Portland Cement**—Cement plants are operated in four southwestern states—Texas, Missouri, Kansas, and Arkansas—with Texas being the largest producer. A plant is now being constructed in a fifth state, Louisiana. A wartime peak was reached in

# Industrial Minerals

## 300 pct increase in the value seven key southwestern states

At upper right, bauxite mining in Arkansas, and pouring of molten magnesium into ingots at Dow Chemical Corp.'s Freeport, Texas, plant. Above, Reynolds Metals Co.'s Hurricane Creek alumina plant south of Little Rock, Ark., and another view of bauxite mining in central Arkansas.

1942 when a total of 28,166,243 bbl were sold. The 38 pct cutback ordered in production reduced the total for 1944 to a point below 1939. Following the war, production steadily increased until in 1948 it reached 31,296,154 bbl, with a value of $69,455,942 representing an increase in tonnage of 93 pct over 1939.

**Sand, Gravel, and Stone**—The trend in sand and gravel production closely follows that of cement. Production rose to a high in 1942, dropped sharply to 1944, and has risen steadily since the war. Production for 1948 was 34,693,666 tons, 166 pct of that for 1939. Stone followed a similar pattern with the 1948 production of 24,958,220 tons representing 147 pct of 1939 production.

**Clay Products**—Figures for clay, excluding refractories, show a steady rise since 1944. The total value for 1948 was $23,209,000, or 230 pct greater than 1939. Texas was the largest producer with $9,648,000 in 1948, followed by Missouri and Kansas with $5,314,000 and $3,050,000 respectively.

**Gypsum**—Production figures were available for only Texas and Arkansas, but Kansas and Oklahoma also produce gypsum. The same trends that apply to other construction materials hold for this mineral, except that the rise since the war has been more marked. The production increased 228 pct over 1939 to a total of 961,247 tons in 1948, of which Texas produced 893,704 tons. The value of gypsum produced in these two states in 1948 was $2,292,863, or 800 pct of the 1939 value.

**Lime**—Missouri and Texas are the important producers of lime in the Southwest although Arkansas and other states are also producers. Because of the wide variety of chemical uses for this material, it did not have the marked production decline during the war which characterizes the products previously discussed. Production increased steadily until 1947, when there was a marked increase in production and an even greater one in the total value of lime produced. In 1948 Missouri and Texas produced a total of 1,178,731 tons of lime valued at $10,528,417, an increase from 1939 of 103 pct in tonnage and 218 pct in price. Missouri produced approximately 85 pct and Texas the remaining 15 pct of this total.

### Other Major Nonmetallics

**Bauxite**—Although considered as a nonmetallic because of its many uses other than in the production of metallic aluminum, the wartime high of over seven million tons reached in 1943 was due to metal demand and the restriction of imported supplies. The production in 1949 was 1,420,853 tons representing 393 pct of that produced in 1939.

**Barite**—Barite finds wide use in ceramics and other manufacture, but its largest use is in the

petroleum industry as a mud weighting material. Production rose steadily to a peak of 667,636 tons in 1946. Although the production in 1949 was down appreciably from this high due to diminishing production in Missouri, the total value is up, showing an increase of 520 pct over 1939. Arkansas mines began operation in 1939 and since 1944 this state has been leading producer.

**Salt**—Kansas, Louisiana, Texas, and New Mexico are all producers of salt. Highest production was reached in 1944 with 3,947,122 tons. The value of production for Texas and New Mexico for 1948 was more than double that of 1939 and the tonnage up more than half.

**Sulphur**—Louisiana and Texas sulphur production has been increasing steadily over the period. No sharp peaks occurred because the nature of mining methods makes this impractical. The 4,978,912 tons produced in 1948 represent an increase of 123 pct since 1939 while in the same period the value has increased 151 pct to a total of $89,600,000. Arkansas is also a small producer of sulphur, derived from sour gas, and it is possible that similar recovery may be made in Oklahoma and Kansas if the supply remains critical.

### Composite Value

The combined annual value of the industrial minerals, discussed individually above, shows a rise to 1942, a levelling off to 1944 and a steady increase to a total value in 1948 of $388,000,000 or an increase of 280 pct in the 10-year period. There has been a volume increase to 177 pct of the 1939 tonnage total.

### Industrial Development in Each State

**Oklahoma**—One of the most important new industrial mineral developments in Oklahoma occurred only 2 years ago with the production of dolomite for the first time. The principal use is for blast furnace flux at Lone Star Steel plant at Daingerfield, Texas. This dolomite is also used for glass manufacturing and fertilizer. The deposit and plant are located in the Arbuckle Mountains in south-central Oklahoma.

Although Oklahoma has had an active glass manufacturing industry for many years, and glass sand has been produced since 1913, production of ground silica started only in 1948 with installation of grinding facilities by Pennsylvania Glass Co. This same year marked the first use of Oklahoma limestone in manufacture of special grades of glass. Oklahoma also reports a big expansion in the processing industries, particularly in the manufacture of glass, lime, cement, and pottery.

**Kansas**—In sympathy with the continued upward trend in the building and construction industry, cement manufacture is up, with production now more than double that in the prewar period. The same applies in general to clay products, brick and tile, and gypsum. Production of manufactured clay products is up 352 pct over the prewar (1939) level and up 40 pct in 1949 over 1948. Salt production in Kansas has remained comparatively stable. Sand and gravel, and crushed and dimension stone are up sharply. The State Survey reports that it seems to detect a tendency on the part of builders to use more nonmetallics, such as composition siding and dimension stone trim, in housing construction. Kansas still leads the United States in the production of volcanic ash, but production is declining because of market conditions.

**New Mexico**—A slight decline was reported in the production of some of New Mexico's large variety of industrial minerals for 1949 over 1948, but the mining industry has now received a tremendous impetus as a result of war preparation. As elsewhere, construction materials are up sharply. New Mexico ranks first in the United States in the production of potash. The deposits in the Carlsbad area began to be developed extensively in the thirties, most of the production going into manufacture of fertilizers. Production of potash rose steadily from 1942 reaching a peak value in 1947 of 34 million dollars. There was a marked increase in the last two years in the production of perlite, and a slight decrease in pumice in 1949.

**Missouri**—Large amounts of barite, cement, clay products (particularly the refractories) lime, and stone are mined in Missouri. Barite production dropped from 278,000 tons in 1948 to 187,000 in 1949. Cement production is up. Lime was slightly less in 1949 than the 1948 high. The production of raw clay, particularly fire clay (75 pct of total clay production) with lesser amounts of diaspore and burley clays, reached one peak in 1942. However 1949 was above the 1942 peak, reaching a total production of 2,400,000 tons. Peak value of manufactured clay products occurred in 1943 when value reached $35,000,000.

**Louisiana**—There are four mines in Louisiana producing rock salt from domes, mines reaching depths of 1000 ft. Fully 50 pct of the annual consumption goes to the chemical industry. The Grand Ecaille mine of Freeport Sulphur had a $5 million expansion in 1947, increasing production 25 pct. Louisiana ranks fourth in production of salt and second in sulphur production in the United States.

**Texas**—Ranking first in the United States in production of sulphur, Texas is also a large producer of cement and gypsum. The State has a variety of newly developed industrial minerals. The mineral industry of the State is based on the abundant common minerals but there are also quantities of less common materials necessary to many industries. As a result of some of these minerals and the abundance of fuel, the Gulf Coastal region has been especially attractive to the chemical industry.

**Arkansas**—During the past decade, Arkansas has seen locally-mined bauxite converted into metallic aluminum for the first time. The Aluminum Co. of America has recently announced plans to build an additional $55 million alumina plant in the state. Local aluminum fabrication has been started and many more plants have been built for processing bauxite for the chemical and other industries. Barite production began in 1939 and has now increased to the point where Arkansas processors supply more barite to industry than the total produced by the rest of the country. Many other mineral industries have also been established or enlarged, including rock wool plants, brick plants, sulphur extraction plants, and a large modern roofing granule plant. The minerals industry holds the most important position in the State's economy that it has ever occupied and more industries are being established yearly.

### Acknowledgments

The help and cooperation of the several state geologists in supplying information for this study is greatly appreciated. Credit for much of the information should also go to the U. S. Bureau of Mines and to the companies that supplied data on their own production.

# ORE CONTROL

## churn-drill hole sludge samples have proved their reliability at Cananea

by F. M. LEONARD, JR.

ORE control at the Cananea pits is based almost entirely on samples taken from churn-drill hole sludges. Occasionally, grab samples of marginal ore are taken as an additional check, but practice over a period of years has proved the reliability of the churn-drill sludge sampling method.

To facilitate the cutting and handling of the sample, a 2-deck splitter was designed which could be fastened to the left or sand line side of the churn-drill platform, thus permitting the operator to empty the sludge from the bailer directly into the splitter without additional effort. The splitter consists of a sturdily constructed iron box which cuts 1/16 part of the sludge passing the top deck, and ⅛ of that 1/16 part on the second deck. Thus 1/128 part of the sludge passing through the splitter is saved and falls through a short pipe in the platform to a 15-gal drum placed directly beneath. The reject falls to the ground at the back of the rig and well in the clear of the container. At first, the splitter was placed to discharge to the side but the reject splashed occasionally on the threads of the left rear screw jack, causing it to wear excessively. This objectionable feature was eliminated by changing the direction of the discharge towards the rear and away from the screw jack.

The sampler in charge takes the sample from the 15-gal drum and passes it through a Jones splitter until a representative amount of approximately one gal of sludge is recovered. This is sent for analysis and the values obtained are assigned to that particular churn-drill hole on the bench assay plans.

Results showed that a 15-gal container was sufficiently large to catch all the sludge from a 40 to 45-ft 9-in. hole, without danger of spillage from overflowing. However, this was not the case when drilling on 60- and 80-ft benches. Carelessness on the part of the sampler caused occasional loss of the sample sludge from overflowing, thus nullifying the accuracy desired. Rather than increase the size of the drum, which would make the sample too heavy for one man to handle; the sampler was instructed to take two samples on 60- and 80-ft benches, each sample being representative of one half of the hole. The mean value of the two samples would then be taken as representative of the entire hole.

Single-row blasting is used exclusively at Cananea. A cutoff of 0.6 pct copper is used to differentiate between ore and waste. In computing the grade of a churn-drill blast, the values of the holes to be blasted are averaged with the grades of the holes in the row directly ahead, in order to obtain the average grade assigned to the blast. Tonnages are computed for each blast and accumulative daily totals of grade and tonnage are kept for each monthly period.

Ore and waste markers are placed on the bench crest immediately after the blast and in full view of the shovel operator. The shift foremen supervise the removal of ore and waste and are responsible for the segregation based upon the location of the markers.

Churn-drill prospecting is used to advantage to more closely delineate ore fringes during the initial stripping operation. This permits the already established final lines to be moved within reasonable limits before the waste removal has proceeded to an advanced stage. As the access roads establishing the benches are completed, and long before stripping actually starts, churn drills can be moved in easily and prospect holes drilled which give, in many instances, valuable additional ore control information. Since the terrain is extremely rugged, it would entail considerable additional expense to secure these data by diamond drilling, before the access roads have been established. Furthermore, a considerable cost differential exists in favor of churn drilling, and the results obtained have proved satisfactory.

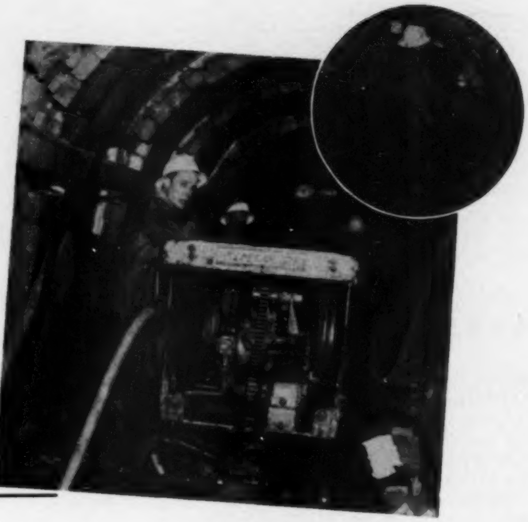
The importance and desirability of an initial diamond-drilling program should not be minimized. At Cananea, where 100 pct core recovery is frequent, the structural studies as well as the assays of the core and sludge are all important factors in ore control.

Prospect churn-drill holes being drilled at the present time rarely exceed 600 ft in depth and are easily drilled with 42T Bucyrus-Erie blasthole drills. Revision of ore outlines resulting from such information has appreciably improved the final ore-to-waste ratio. In one instance a considerable amount of ore was made available that had been overlooked entirely in the original estimates through lack of sufficient information.

Once ore removal has begun in the pit occasional prospect holes are drilled from the floors of the working benches to approximately 50 ft below the calculated pit bottom. The location of such holes depends on major variations in predicted bench ore outlines based on the initial prospecting program. A closer ore control can be kept in this way as the pit development proceeds.

MR. LEONARD is Pit Engineer at the Cananea Consolidated Copper Co., Cananea, Sonora, Mexico. This paper was originally presented before the Open-Pit Subdivision, Arizona Section, AIME.

# COLORADO'S LEADVILLE TUNNEL



Steel sets and close timber lagging hold off fractured quartzite, while high on the muck pile at the face (inset) miners rush to set timber in the crumbling rock. An Eimco 21 loader stands by, ready to clean up.

THE Leadville tunnel, a Bureau of Mines project designed to unseal Colorado's rich but flooded lead, zinc, and manganese mines, is still being advanced, although the work is encountering severe difficulties. Work on the tunnel, begun in 1943, was dropped for lack of funds in 1945, and started again last September. The tunnel is one of the nation's toughest mining jobs. Fifty firms and individuals, who were asked to bid on the job of continuing beyond the 6600-ft mark, didn't even answer. The work was finally taken over by the Utah Construction Co. of Salt Lake City. Since last September, the face has been moved 1000 ft closer to the flooded Leadville district mines, and to the hoped-for length of 17,300 ft. Some apparent success has already been noted, with an unusual decline in the water level in some major mine shafts reported this winter.

One of the severest tests encountered by the tunnel drivers was a major fault at 7360 ft that contained water and two or three ft of soupy gouge or soft material, with cavities 40 ft high reported. This, together with severely fractured quartzite in the underlying or footwall of the fault, necessitated special timbering (spiling and breastboards) for the last 240 ft and has slowed progress temporarily.

The distance that the tunnel will be extended under the current contract cannot be estimated definitely because of several unknown factors, such as the uncertain rock formations and the volume of water that may be encountered. But the Bureau hopes that it can be advanced at least 2500 ft more, or to the Robert Emmett shaft, which is linked underground to some of the richest flooded mine workings of the Leadville district. This 10,100-ft tunnel section should then drain most, if not all, of the Fryer Hill basin and a large part of the Carbonate Hill basin. The portal is on the East Fork of the Arkansas River, about 1½ miles north of Leadville, at an elevation of 9960 ft.

Plans for the Bureau's drainage project provide for extending the tunnel to a total length of 17,300 ft, including a 3500-ft lateral to drain Leadville's Downtown basin and another 2400-ft lateral to unwater the Iron Hill basin. Completion of the full project is dependent upon Congress appropriating funds in addition to the $500,000 now available in cash and contract authorizations.

From 1860 to 1944 Lake County mines produced gold, silver, copper, lead, and zinc ores valued at $462,600,000—nearly all of it from the Leadville district. There still is a lot of ore available according to a War Production Board survey made during World War II.

Pumping of water from the many miles of underground workings had proved too costly, and tunneling was selected as the only economical method for draining a large number of the mines. The tunnel will provide continued drainage, access for exploration and development of orebodies, and possibly cheaper hauling.

The tunnel's cross-section was reduced from 9x10½ to 7x9 ft to save funds and facilitate driving. Timber sets of Douglas fir are used in extremely heavy ground, and two-piece steel sets are employed in zones requiring less support. Some sections of the tunnel stand without support.

Most of the bore was in quartzite until it reached 7285 ft, where the Peerless shale formation was encountered. At 7360 ft, when the as yet unidentified fault was found, the tunnel re-entered Sawatch quartzite.

Thus far, the flow of water from the tunnel has varied between 1650 and 2675 gpm, and has not presented a serious handicap to operations. Tunnel crews hope, of course, that they will not strike any major head of water until they are much nearer their objective, for it would impede the advance. As a protective measure, however, a drill hole is maintained 20 ft ahead of the face.

Already the water level apparently is being lowered in some major mine shafts, which still are a considerable distance ahead of the bore. Regular measurements at several of these shafts now show more than a normal decline for the winter season.

# An Approximate Method of Predicting and Comparing Expected Results When Dewatering Coal by Centrifuges

by Orville R. Lyons

CENTRIFUGAL force has been utilized for the dewatering of fine coal for over 50 years by means of machines commonly called centrifugal dryers. In any centrifuge the coal and water are subjected to a spinning action which usually increases in intensity as the coal progresses through the machine. This spinning action, or the centrifugal force that it induces, tears water away from coal particles and produces a dewatered coal. The effectiveness of the dewatering action for any particular machine is governed by the size-consist of the coal and the centrifugal force imparted to the water on the coal.

Four makes of centrifuge are currently being used to dewater fine bituminous coal in the United States. These include the vertical, basket-screen C.M.I. (Centrifugal and Mechanical Industries) Carpenter, Reineveld, and the horizontal solid-bowl Bird.

The C.M.I. and Reineveld centrifuges are similar in construction and are variations of the Elmore centrifuge, varying principally in the slope of the basket, operating speed, size of perforations in the basket, and diameter of the basket. The same operating description suffices for both. These centrifuges are made up of two rotating elements, an outside conical screen frame and an inside solid cone which carries spiral pusher blades. The screen frame is supported by a hollow shaft, and the solid cone by a spindle shaft passing through the hollow shaft. Both the screen frame and the solid cone rotate at high speeds; the solid cone, with its scraping flights, rotating somewhat more slowly than the screen.

The wet coal enters the machine at the top, falls on the cone, and is thrown against the screen by centrifugal force. The coal slides down the screen until it meets the upper end of the flights, where it is moved slowly along the flights until discharged at the bottom. The effluent passes through the sieve basket or screen and discharges into a launder.

The Carpenter centrifuge consists of a conical rotating element with a vertical axis, built up of three rows of perforated stainless-steel plates or stainless-steel wedge-wire or round-wire sections cut and rolled to conform to the surface of the cone. Wet material is delivered to a conical hopper inside the centrifuge casing and is distributed in a thin, even layer over the inner surface of the cone by a disk mounted on the rotor shaft. Impacting of the coal against the screen and the centrifugal force exerted as the material moves downwards creates a dewatering effect. The moisture is forced through the coal bed and then through the perforated plates of the basket, collecting in a circular trough built into the centrifuge. The effluent is conducted from the trough through the centrifuge casing by outlet pipes. The dewatered coal is discharged over the inside bottom edge of the rotor.

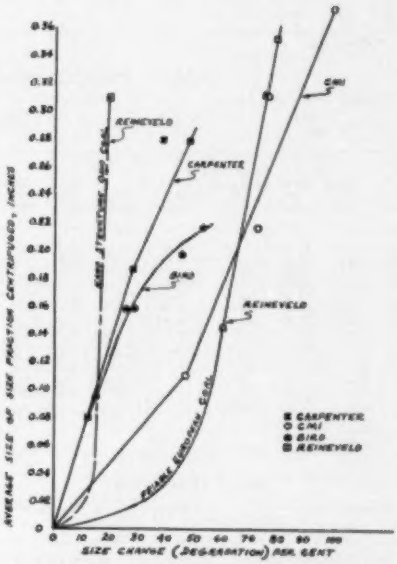



**Fig. 1—Relationships existing between average size of a given size fraction and its percentage change when dewatering coal by means of centrifuges.**

The Bird centrifuge consists of a tank or truncated conical shell, which is revolved at the desired speed by means of a drive sheave. A screw conveyor rotates inside the cone or *bowl* at a slightly lower speed in the same direction of rotation. The feed entrance, in the center of the large end of the truncated cone, is high enough to allow formation of a pool of slurry. Adjustable effluent-discharge ports are located in the large end of the *bowl* so the level of the liquid can be regulated. The solids are moved forward by the screw conveyor as fast as deposited and carried above the level of the pool for an interval before leaving the *bowl*.

In the past these four makes of centrifuge could be compared only by indirect means. The author published a rough comparison method in 1949[1] but

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Discussion on this paper, TP 3044F, may be sent (2 copies) to AIME before June 29, 1951. Manuscript, Nov. 15, 1950. St. Louis Meeting, February 1951.



*This page of Transactions is a continuation from p. 372. The missing pages appeared in Mining Engineering.*

## Table I. Carpenter Centrifuge Feed and Products Size-Consist Data

**Carpenter No. 1 and Carpenter No. 2**

| Size Mesh[a] | Carpenter No. 1 Feed Wt, Pct | Carpenter No. 1 Cake Wt, Pct | Carpenter No. 1 Cake Plus Effluent Wt, Pct | Carpenter No. 2 Feed Wt, Pct | Carpenter No. 2 Cake Wt, Pct | Carpenter No. 2 Cake Plus Effluent Wt, Pct |
|---|---|---|---|---|---|---|
| ⅜x4 | 20.0 | 14.5 | 12.4 | 24.0 | 17.0 | 12.6 |
| 4x14 | 44.5 | 47.0 | 41.8 | 38.5 | 49.5 | 38.0 |
| 14x48 | 30.0 | 31.0 | 35.8 | 28.0 | 23.5 | 34.3 |
| 48x100 | 3.5 | 4.0 | 5.5 | 4.5 | 5.0 | 6.7 |
| 100x200 | 1.0 | 1.5 | 1.8 | 1.5 | 2.0 | 2.5 |
| —200 | 1.0 | 2.0 | 2.7 | 3.5 | 3.0 | 5.9 |

**Carpenter No. 3**

| Size Mesh | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
|---|---|---|---|
| 5/16x10 | 70.2 | 55.0 | 50.8 |
| 10x14 | 8.6 | 20.1 | 19.7 |
| 14x48 | 14.7 | 17.1 | 17.5 |
| 48x100 | 5.0 | 5.5 | 7.2 |
| —100 | 1.5 | 2.3 | 4.8 |

**Carpenter No. 4**

| Size Mesh[a] | Dewatered Cake Wt, Pct |
|---|---|
| ¼x4 | 12.4 |
| 4x8 | 15.5 |
| 8x10 | 12.3 |
| 10x14 | 10.3 |
| 14x28 | 12.7 |
| 28x48 | 8.9 |
| 48x65 | 9.9 |
| 65x100 | 6.4 |
| 100x200 | 4.8 |
| —200 | 6.8 |

**Carpenter No. 5**

| Size Mesh[a] | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
|---|---|---|---|
| 8x10 | 7.7 | 9.3 | 2.8 |
| 10x14 | 12.4 | 15.2 | 7.6 |
| 14x20 | 21.3 | 23.6 | 17.8 |
| 20x28 | 17.1 | 19.0 | 19.2 |
| 28x35 | 14.4 | 14.1 | 14.6 |
| 35x48 | 7.9 | 6.6 | 7.6 |
| 48x60 | 3.2 | 2.4 | 2.9 |
| 60x100 | 6.4 | 3.9 | 6.4 |
| 100x200 | 4.8 | 2.4 | 4.8 |
| —200 | 4.8 | 3.5 | 16.3 |

[a] Tyler mesh.

## Table II. C.M.I. Centrifuge Feed and Products Size-Consist Data

**C.M.I. No. 1 and C.M.I. No. 2**

| Size Mesh[a] | C.M.I. No. 1 Feed Wt, Pct | C.M.I. No. 1 Cake Wt, Pct | C.M.I. No. 1 Cake Plus Effluent Wt, Pct | C.M.I. No. 2 Cake Wt, Pct |
|---|---|---|---|---|
| 6x8 | 6.13 | 10.62 | 3.19 | 16.96 |
| 8x10 | 2.78 | 5.30 | 1.62 | 8.69 |
| 10x14 | 5.43 | 9.61 | 3.73 | 12.01 |
| 14x20 | 12.00 | 22.03 | 14.37 | 18.26 |
| 20x28 | 19.27 | 21.17 | 21.79 | 18.16 |
| 28x35 | 11.68 | 12.28 | 11.96 | 9.82 |
| —35 | 42.71 | 18.90 | 43.32 | 15.90 |

**C.M.I. No. 3 and C.M.I. No. 4**

| Size Mesh[b] | C.M.I. No. 3 Feed Wt, Pct | C.M.I. No. 3 Cake Wt, Pct | C.M.I. No. 3 Cake Plus Effluent Wt, Pct | C.M.I. No. 4 Feed Wt, Pct | C.M.I. No. 4 Cake Wt, Pct | C.M.I. No. 4 Cake Plus Effluent Wt, Pct |
|---|---|---|---|---|---|---|
| + ¼ | 1.7 | 0.6 | 0.4 | | | |
| ¼x4 | 10.9 | 6.8 | 4.2 | 1.1 | 0.5 | 0.3 |
| 4x8 | 38.6 | 31.7 | 23.0 | 9.0 | 14.8 | 7.3 |
| 8x10 | 11.6 | 14.1 | 10.0 | 8.9 | 15.9 | 10.9 |
| 10x16 | 10.0 | 13.6 | 9.9 | 15.4 | 19.8 | 12.1 |
| 16x20 | 7.8 | 11.3 | 10.6 | 12.1 | 17.8 | 12.7 |
| 20x30 | 5.2 | 6.8 | 9.8 | 10.5 | 10.6 | 10.4 |
| 30x40 | 4.5 | 5.3 | 10.3 | 10.6 | 7.7 | 10.8 |
| 40x50 | 3.0 | 3.4 | 6.5 | 6.1 | 4.1 | 6.7 |
| 50x60 | 1.3 | 1.4 | 2.2 | 1.6 | 1.7 | 2.5 |
| 60x100 | 2.0 | 2.4 | 5.4 | 5.6 | 2.7 | 5.9 |
| 100x200 | 1.0 | 1.6 | 2.4 | 5.1 | 1.7 | 5.2 |
| —200 | 2.4 | 2.0 | 5.4 | 14.0 | 2.7 | 15.2 |

**C.M.I. No. 5**

| Size Mesh[a] | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
|---|---|---|---|
| + ¼ | 7.6 | 4.6 | 3.9 |
| ¼x3/16 | 12.4 | 9.7 | 8.3 |
| 3/16x⅛ | 17.6 | 14.8 | 12.6 |
| ⅛x10 | 18.8 | 18.9 | 16.1 |
| 10x20 | 15.3 | 18.9 | 16.1 |
| 20x28 | 6.0 | 8.0 | 6.9 |
| 28x35 | 5.1 | 6.9 | 6.5 |
| 35x65 | 7.1 | 8.7 | 10.1 |
| 65x100 | 2.4 | 2.8 | 4.1 |
| 100x200 | 2.7 | 3.0 | 5.3 |
| —200 | 5.0 | 3.7 | 10.1 |

**C.M.I. No. 6**

| Size Mesh[a] | Cake Wt, Pct |
|---|---|
| 6x8 | 4.59 |
| 8x10 | 13.76 |
| 10x28 | 52.29 |
| 28x48 | 16.52 |
| 48x100 | 6.42 |
| 100x200 | 2.75 |
| —200 | 3.67 |

[a] Tyler.
[b] U.S. Standard.

## Table II (Continued)

**C.M.I. No. 7**

| Size Mesh[a] | Cake Wt, Pct |
|---|---|
| +4 | 0.8 |
| 4x8 | 4.7 |
| 8x14 | 34.5 |
| 14x28 | 30.1 |
| 28x48 | 16.3 |
| 48x100 | 6.8 |
| 100x200 | 2.9 |
| —200 | 3.9 |

**C.M.I. No. 8**

| Size Mesh[a] | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
|---|---|---|---|
| + ⅜ | 1.4 | | |
| ⅜x¼ | 6.9 | 3.0 | 2.6 |
| ¼x3/16 | 10.2 | 7.5 | 6.6 |
| 3/16x⅛ | 13.5 | 10.8 | 9.6 |
| ⅛x10 | 14.1 | 12.3 | 10.9 |
| 10x20 | 13.7 | 17.9 | 15.9 |
| 20x28 | 5.7 | 8.6 | 7.8 |
| 28x48 | 13.6 | 16.5 | 17.7 |
| 48x65 | 7.0 | 6.8 | 8.2 |
| 65x100 | 6.4 | 6.2 | 7.7 |
| 100x200 | 4.8 | 5.8 | 6.8 |
| —200 | 2.7 | 4.6 | 6.2 |

[a] Tyler.

this comparison did not provide any direct means for determining centrifuge capacity or predicting operating results, and it was obvious that methods needed to be developed for these purposes.

### Elements of Comparison

To develop a reasonably accurate method for predicting and comparing the results to be expected when dewatering coal by means of centrifuges, operating data were collected for centrifuge installations from as many sources as possible. In every case the data obtained were for actual installations tested under operating conditions. In the majority of cases this information was obtained by plant preparation engineers for their own purposes and was given to the author upon request. The major portion of the data obtained for C.M.I. and Carpenter centrifuges were obtained at installations dewatering hard or medium hard structure coals such as Illinois No. 6 or Ohio-Pittsburgh No. 8. The Bird data were obtained for both hard and friable structure coals, with the hard structure coals predominating. The Reineveld data were obtained primarily for European installations treating medium hard to very friable structure coals, but some data were obtained for an installation dewatering a hard structure Ohio coal.

*The Crushing or Degradation Effect:* Observations made by the author and by others, revealed that centrifuges handling very coarse coal or refuse material tended to produce a dusty cake. This condition could exist only if a major portion of the larger particles in the feed were degraded at, or just prior to, discharge from the centrifuge. Based on these observations, it seemed logical to assume that, for first approximation purposes, 100 pct of the degradation in all sizes occurred just prior to or just after discharge from the centrifuge. Later calculations show this assumption to be reasonably true.

*Correlating Degradation and Particle Size:* Degradation is defined readily in general, but means of measuring degradation in a preparation plant when considering a heterogeneous mixture of sizes of coal—even when the coal substance is more or less homogeneous—have not been available in the past. Studies of feed and cake size-consists have indi-

## Table III. Bird Centrifuge Feed and Products Size-Consist Data

| Bird No. 1 | | | |
|---|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
| 4x6 | 21.7 | 15.7 | 15.3 |
| 6x10 | 26.2 | 20.0 | 19.4 |
| 10x14 | 9.0 | 19.3 | 18.7 |
| 14x20 | 8.4 | 11.0 | 10.7 |
| 20x28 | 7.7 | 6.9 | 6.7 |
| 28x35 | 5.3 | 5.5 | 5.3 |
| 35x48 | 6.2 | 3.7 | 3.6 |
| 48x65 | 4.4 | 4.4 | 4.3 |
| 65x100 | 3.6 | 3.7 | 3.6 |
| 100x150 | 2.0 | 2.1 | 2.0 |
| 150x200 | 1.5 | 1.9 | 1.9 |
| —200 | 4.0 | 5.8 | 8.5 |

| Bird No. 2 | | | |
|---|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
| 6x10 | 26.60 | 22.90 | 22.3 |
| 10x14 | 16.55 | 15.03 | 14.6 |
| 14x28 | 19.35 | 19.30 | 18.8 |
| 28x48 | 6.64 | 9.32 | 9.1 |
| 48x100 | 5.40 | 7.17 | 7.0 |
| 100x200 | 5.26 | 5.98 | 5.8 |
| —200 | 20.20 | 20.30 | 22.4 |

| Bird No. 3 | | | |
|---|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
| 3x6 | 17.2 | 10.7 | 9.2 |
| 6x10 | 22.6 | 18.9 | 16.3 |
| 10x14 | 9.5 | 10.6 | 9.1 |
| 14x28 | 12.5 | 17.4 | 15.0 |
| 28x48 | 9.5 | 13.7 | 11.8 |
| 48x100 | 5.7 | 8.7 | 7.5 |
| 100x200 | 3.7 | 6.3 | 5.4 |
| —200 | 19.3 | 13.7 | 25.7 |

| Bird No. 4 | |
|---|---|
| Size Mesh* | Cake Wt, Pct |
| 3x6 | 9.8 |
| 6x10 | 16.6 |
| 10x14 | 9.7 |
| 14x28 | 18.1 |
| 28x48 | 15.5 |
| 48x100 | 9.6 |
| 100x200 | 6.4 |
| —200 | 14.3 |

| Bird No. 5 | | | |
|---|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
| ¼x10 | 50.60 | 46.20 | 37.40 |
| 10x14 | 10.60 | 10.20 | 8.25 |
| 14x20 | 6.24 | 7.63 | 6.20 |
| 20x28 | 4.74 | 6.38 | 5.10 |
| 28x35 | 3.65 | 5.10 | 4.15 |
| 35x48 | 2.07 | 3.82 | 3.10 |
| 48x65 | 1.71 | 3.06 | 2.50 |
| 65x100 | 1.48 | 2.80 | 2.30 |
| 100x200 | 2.37 | 4.34 | 3.50 |
| —200 | 16.54 | 10.47 | 27.50 |

* Tyler mesh.

## Table III (Continued)

| Bird No. 6 | | | |
|---|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
| ¼x4 | 31.7 | 16.2 | 14.9 |
| 4x8 | 28.1 | 29.8 | 27.5 |
| 8x10 | 11.1 | 18.4 | 17.0 |
| 10x20 | 11.7 | 13.6 | 12.8 |
| 20x35 | 6.1 | 7.4 | 6.8 |
| 35x48 | 2.3 | 2.4 | 2.2 |
| 48x65 | 1.9 | 2.2 | 2.05 |
| 65x100 | 1.4 | 2.2 | 2.05 |
| —100 | 5.7 | 7.8 | 15.0 |

| Bird No. 7 | |
|---|---|
| Size Mesh* | Cake Wt, Pct |
| 3x6 | 9.8 |
| 6x10 | 16.6 |
| 10x14 | 9.7 |
| 14x28 | 18.1 |
| 28x48 | 15.5 |
| 48x100 | 9.6 |
| 100x200 | 6.4 |
| —200 | 14.3 |

| Bird No. 8 | |
|---|---|
| Size Mesh* | Cake Wt, Pct |
| 3x6 | 13.1 |
| 6x10 | 22.7 |
| 10x14 | 11.2 |
| 14x28 | 17.1 |
| 28x48 | 12.0 |
| 48x100 | 7.1 |
| 100x200 | 5.2 |
| —200 | 11.6 |

| Bird No. 9 | |
|---|---|
| Size Mesh* | Cake Wt, Pct |
| 14x28 | 4.4 |
| 28x35 | 5.7 |
| 35x48 | 5.9 |
| 48x65 | 6.2 |
| 65x100 | 5.9 |
| 100x200 | 12.4 |
| —200 | 59.5 |

| | Bird No. 10 | Bird No. 11 | Bird No. 12 | Bird No. 13 |
|---|---|---|---|---|
| Size Mesh* | Cake Wt, Pct | Cake Wt, Pct | Cake Wt, Pct | Cake Wt, Pct |
| 4x6 | 8.7 | 2.94 | 17.98 | 19.52 |
| 6x10 | 37.4 | 19.30 | 24.40 | 23.90 |
| 10x14 | 10.8 | 12.03 | 9.06 | 10.70 |
| 14x28 | 16.3 | 20.71 | 15.77 | 15.46 |
| 28x48 | 10.3 | 14.17 | 10.01 | 9.84 |
| 48x100 | 4.5 | 10.47 | 6.93 | 6.28 |
| 100x200 | 3.0 | 5.19 | 3.60 | 3.81 |
| —200 | 9.0 | 15.19 | 12.25 | 10.49 |

| | Bird No. 14 | Bird No. 15 |
|---|---|---|
| Size Mesh* | Cake Wt, Pct | Cake Wt, Pct |
| ¼x6 | 15.7 | 16.7 |
| 6x10 | 40.3 | 26.3 |
| 10x14 | 13.9 | 10.9 |
| 14x20 | 6.2 | 11.4 |
| 20x28 | 6.4 | 8.9 |
| 28x35 | 3.3 | 8.7 |
| 35x48 | 3.9 | 5.9 |
| 48x65 | 2.7 | 4.1 |
| 65x100 | 2.1 | 3.2 |
| 100x150 | 1.4 | 1.8 |
| 150x200 | 1.0 | 1.2 |
| —200 | 3.1 | 3.9 |

* Tyler mesh.

cated that degradation was most severe in the larger sizes and apparently progressively less severe in the smaller sizes when centrifuging coal. It was concluded, after studying the operating data available, that degradation for any size fraction in a mixture of sizes could best be approximated by determining degradation for a number of closely sized fractions and plotting the results. Then degradation for intervening sizes could be read from the graph. From the operating data previously mentioned it was possible to determine the percentage differences for the top size material in a particular feed and the same size of material in the combined cake and effluent at the same installation, and then calculate the size change or degradation in per cent of the feed.

Example: ¼ x ⅛-in. coal in feed = 20 pct by weight of feed. ¼ x ⅛-in. coal in combined cake and effluent = 15 pct by weight of combined cake and effluent solids

$$\text{then degradation pct} = \frac{20\text{-}15}{20} \times 100 = 25$$

Then, from data for installations having various top sizes in the feeds, it was possible to develop for any particular make of centrifuge degradation particle-size relationships as shown in Fig. 1. The graph indicating Reineveld degradation when treating a hard structure coal represents a calculated guess based on the one point available and was

## Table III (Continued)

| Bird No. 16 | | Bird No. 17 | |
|---|---|---|---|
| Size Mesh* | Cake Wt, Pct | Size Mesh* | Cake Wt, Pct |
| 35x48 | 4.0 | 4x10 | 43.40 |
| 48x100 | 14.2 | 10x14 | 13.00 |
| 100x200 | 21.8 | 14x20 | 8.56 |
| 200x250 | 15.8 | 20x28 | 6.72 |
| 250x325 | 27.1 | 28x35 | 5.10 |
| —325 | 17.1 | 35x48 | 3.00 |
| | | 48x65 | 2.50 |
| | | 65x100 | 2.32 |
| | | 100x200 | 3.44 |
| | | —200 | 9.26 |

* Tyler mesh.

included because it represents the only available data.

*Size-Consist of Degraded Material:* Studies of size-consist data for fine coal made over a period of years by many competent observers[3-4] reveal that the size compositions of most coals conform to a definite pattern. It therefore seems reasonable to assume that any breakage occurring in a centrifuge would tend to have essentially the same size distribution as particles of comparable size in the original feed. For example, coal in the range of ¼ x ⅛ in. would provide a degraded product having the same size-consist as the —⅛ x 0-in. coal in the centrifuge feed.

*Correlating Particle Size and Surface Moisture:*

## Table IV. Reineveld Centrifuge Feed and Products Size-Consist Data

| Reineveld No. 1 | | | Reineveld No. 2 | |
|---|---|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct | Feed Wt, Pct | Cake Wt, Pct |
| 5/16x7 | 55.2 | 42.1 | 42.9 | 35.6 |
| 7x16 | 23.6 | 29.4 | 31.4 | 33.3 |
| 16x32 | 9.0 | 10.6 | 12.0 | 13.0 |
| 32x115 | 10.5 | 14.5 | 11.7 | 14.4 |
| —115 | 1.7 | 3.4 | 2.0 | 3.7 |

| Reineveld No. 3 | | | |
|---|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
| ⅜x5/16 | 12.84 | 3.21 | 2.7 |
| 5/16x¼ | 5.32 | 3.18 | 2.6 |
| ¼x4 | 12.41 | 5.75 | 4.9 |
| 4x7 | 21.83 | 16.70 | 13.9 |
| 7x9 | 19.51 | 21.76 | 18.2 |
| 9x16 | 15.16 | 19.33 | 16.2 |
| 16x32 | 7.20 | 14.33 | 12.2 |
| 32x60 | 3.15 | 8.10 | 10.0 |
| —60 | 2.58 | 7.64 | 19.3 |

| Reineveld No. 4 | | |
|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct |
| 5/16x7 | 14.2 | 9.6 |
| 7x9 | 7.3 | 6.9 |
| 9x16 | 24.6 | 24.8 |
| 16x20 | 15.1 | 13.2 |
| 20x32 | 15.4 | 21.2 |
| 32x65 | 15.1 | 14.6 |
| —65 | 8.3 | 7.1 |

| Reineveld No. 5 | | |
|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct |
| ½x⅜ | 1.00 | 0.78 |
| ⅜x4 | 17.18 | 12.10 |
| 4x7 | 14.00 | 10.18 |
| 7x12 | 19.70 | 24.14 |
| 12x16 | 17.82 | 21.50 |
| 16x32 | 16.56 | 18.58 |
| 32x65 | 6.78 | 7.32 |
| —65 | 7.26 | 5.30 |

| Reineveld No. 6 | | | |
|---|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
| ⅜x¼ | 0.46 | 0.25 | 0.11 |
| ¼x5 | 17.07 | 8.68 | 7.59 |
| 5x9 | 26.28 | 18.63 | 16.00 |
| 9x16 | 30.77 | 30.17 | 25.90 |
| 16x32 | 9.10 | 10.17 | 10.90 |
| 32x60 | 3.98 | 10.60 | 12.60 |
| —60 | 12.34 | 21.30 | 26.80 |

* Tyler mesh.

## Table IV (Continued)

| Reineveld No. 7 | | | |
|---|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct | Cake Plus Effluent Wt, Pct |
| 4x7 | 1.0 | 1.1 | 0.4 |
| 7x14 | 17.9 | 16.5 | 11.2 |
| 14x32 | 44.9 | 44.6 | 35.3 |
| 32x60 | 25.8 | 20.6 | 28.9 |
| 60x100 | 7.9 | 13.0 | 14.7 |
| 100x150 | 1.3 | 1.6 | 2.7 |
| 150x200 | 0.4 | 0.8 | 1.6 |
| —200 | 0.8 | 1.8 | 5.2 |

| Reineveld No. 8 | | |
|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct |
| 3x4 | 10.1 | 7.2 |
| 4x5 | 6.0 | 5.9 |
| 5x7 | 13.5 | 11.4 |
| 7x9 | 24.0 | 25.6 |
| 9x16 | 28.1 | 33.3 |
| 16x32 | 4.5 | 5.0 |
| 32x48 | 3.8 | 3.5 |
| 48x65 | 3.2 | 2.6 |
| 65x150 | 2.1 | 2.0 |
| —150 | 4.7 | 3.5 |

| Reineveld No. 9 | | |
|---|---|---|
| Size Mesh* | Feed Wt, Pct | Cake Wt, Pct |
| +¼ | 1.7 | 1.6 |
| ¼x3/16 | 6.2 | 5.1 |
| 3/16x⅛ | 21.4 | 19.8 |
| ⅛x10 | 17.3 | 19.0 |
| 10x20 | 23.2 | 26.3 |
| 20x28 | 7.7 | 8.4 |
| 28x48 | 12.8 | 12.2 |
| 48x100 | 5.2 | 4.3 |
| 100x200 | 1.9 | 1.4 |
| —200 | 2.6 | 1.9 |

* Tyler mesh.

## Table V. Miscellaneous Carpenter Centrifuge Data

| Centrifuge No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Location | Penna. | Penna. | Penna. | Illinois | Illinois |
| Average particle size of cake, in. | 0.0939 | 0.0898 | 0.1043 | 0.0717 | 0.0312 |
| Surface moisture content of cake, wet basis, pct | 5.2 | — | 4.8 | 6.5 | 9.3 |
| Average size of largest size fraction, in. | 0.2800 | 0.2800 | 0.1888 | — | 0.079 |
| Change in quantity of largest size fraction, pct* | 38.0 | 47.4 | 27.7 | — | 12.75 |
| Feed, tons per hr | 35 | 55 | — | — | 31.2 |
| Cake, tons per hr | 30 | 42 | — | — | 18.7 |

* Degradation pct.

Test data obtained for geared-weight types of vibrating screens[5] provided a definite correlation between the average particle size of the dewatered cake and the average surface moisture content of the cake when seam moisture and inherent moisture were considered synonymous. Since this provided good correlations for vibrating screens it was assumed that the same relationship should provide correlations for centrifuges or any other type of dewatering device. Each make of centrifuge or dewatering device would be expected to have its own particular size-composition surface-moisture relationship, however. The relationships developed for centrifuges are shown in Fig. 2.

Based on the above approximations and correlations it is possible to predict, within reasonable limits, the results to be expected when dewatering fine coal by means of centrifuges and to compare the 69-in. Carpenter with the 48-in. C.M.I., the 54-in. Bird, and the "small" Reineveld. This comparison does not include the new "small" C.M.I.


Fig. 2—Relationships existing between size of product and surface moisture content when dewatering coal by means of centrifuges.

### Comparison Data

Tables I, II, III, and IV contain size-consist data for feed, cake, and combined cake and effluent solids


Fig. 3—Relation between average sizes of dewatered cake solids and composite cake plus effluent solids.

## Table VI. Miscellaneous C.M.I. Centrifuge Data

| Centrifuge No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Location | Illinois | Illinois | Indiana | Illinois | Penna. | Ohio | Ohio | Penna. |
| Average particle size of cake, in. | 0.04 | 0.048 | 0.063 | 0.0591 | 0.068 | 0.0418 | 0.0463 | 0.0688 |
| Surface moisture content of cake, wet basis, pct | 8.5 | 8.0 | 4.6 | 6.5 | | 8.0 | 7.5 | |
| Average size of largest size fraction, in. | 0.112 | | 0.312 | 0.2175 | 0.312 | | | 0.0380 |
| Change in quantity of largest size fraction, pct[a] | 47.9 | | 76.4 | 72.6 | 48.8 | | | 100.0 |
| Feed, tons per hr | 50.0 | 50.0 | 58.3 | 35.5 | 60.0 | 34.6 | 44.0 | 50 |
| Cake, tons per hr | 15.0 | 12.0 | 42.3 | 17.5 | 51.0 | 21.9 | 30.7 | 44 |

[a] Degradation pct.

## Table VII. Miscellaneous Bird Centrifuge Data

| Centrifuge No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Location | W. Va. | W. Va. | Penna. | Penna. | Penna. | Penna. | Penna. | Penna. | Kentucky |
| Average particle size of cake, in. | 0.0640 | 0.0405 | 0.051 | 0.0514 | 0.0857 | 0.1006 | 0.0475 | 0.058 | 0.0064 |
| Surface moisture content of cake, wet basis, pct | 12.3 | 18.5 | 15.3 | 17.0 | 6.2 | | 15.3 | 13.1 | 26.3 |
| Average size of largest size fraction, in. | 0.1580 | 0.0980 | 0.1970 | | 0.1575 | 0.2175 | | | |
| Change in quantity of largest size fraction, pct[a] | 29.5 | 16.2 | 46.5 | | 26.1 | 52.9 | | | |
| Feed, tons per hr | 35 | 40.0 | 63 | 50 | 41.2 | 40 | | | |
| Cake, tons per hr | 33.1 | 36.9 | 54 | 43.7 | 33.4 | 36.0 | | | |

[a] Degradation pct.

## Table VII (Continued)

| Centrifuge No. | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|
| Location | W. Va. | W. Va. | W. Va. | W. Va. | W. Va. | W. Va. | Penna. | Penna. |
| Average particle size of cake, in. | 0.0644 | 0.0413 | 0.0655 | 0.0602 | 0.0642 | 0.0745 | 0.0038 | 0.0756 |
| Surface moisture content of cake, dry basis, pct | 9.8 | 15.2 | 13.5 | 11.1 | 6.2 | 9.5 | 27.5 | 8.8 |
| Cake, tons per hr | 13.5 | 28.0 | 20.0 | 20.0 | | | | |

## Table VIII. Miscellaneous Reineveld Centrifuge Data

| Centrifuge No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Location | Holland | Holland | Belgium | France | Holland | Hungary | Great Britain | Rhineland | Ohio |
| Average particle size of cake, in. | 0.1158 | 0.1057 | 0.0882 | 0.0846 | 0.0835 | 0.0633 | 0.0333 | 0.0890 | 0.0826 |
| Surface moisture content of cake, wet basis, pct | 5.0 | 7.2 | 5.3 | 6.4 | 5.5 | 7.5 | 8.8 | 5.1 | 6.8 |
| Average size of largest size fraction, in. | | | 0.3330 | | | 0.3125 | 0.1475 | | 0.3125 |
| Change in quantity of largest size fraction, pct[a] | | | 79 | | | 76 | 60 | | 15.3 |
| Feed, tons per hr | | | 41.8 | 55 | 80 | 60 | 38 | | |
| Cake, tons per hr | 44.0 | 88.0 | 34.7 | 43 | 60.5 | 54 | 25.3 | 30.5 | 40.0 |

[a] Degradation pct.

**Table IX. Carpenter No. 1 Basic Degradation Data**

| Size Mesh* | Average Size, In. | Feed Wt, Pct | Degradation Pct | Cake Plus Effluent Wt, Pct |
|---|---|---|---|---|
| ⅜x4 | 0.2000 | 20.0 | 48.0 | 12.4 |
| 4x14 | 0.1155 | 44.5 | 17.5 | 41.8 |
| 14x48 | 0.0288 | 30.0 | 4.5 | 35.8 |
| 48x100 | 0.0087 | 3.5 | 1.5 | 5.5 |
| 100x200 | 0.0034 | 1.0 | 0.8 | 1.8 |
| —200 | 0.0029 | 1.0 | | 2.7 |

* Tyler mesh.

**Table X. Carpenter No. 1 Changing Size-Consist Relationships**

| Size Mesh* | Feed Wt, Pct | 4x0 Wt, Pct | 14x0 Wt, Pct | 48x0 Wt, Pct | 100x0 Wt, Pct | 200x0 Wt, Pct |
|---|---|---|---|---|---|---|
| ⅜x4 | 20.0 | | | | | |
| 4x14 | 44.5 | 55.7 | | | | |
| 14x48 | 30.0 | 37.5 | 84.6 | | | |
| 48x100 | 3.5 | 4.4 | 9.8 | 63.6 | | |
| 100x200 | 1.0 | 1.2 | 2.8 | 18.2 | 50.0 | |
| —200 | 1.0 | 1.2 | 2.8 | 18.2 | 50.0 | 100.0 |
| Pct of Feed | 100.0 | 80.0 | 35.5 | 5.5 | 2.0 | 1.0 |

* Tyler mesh.

for Carpenter, C.M.I., Bird, and Reineveld installations. Tables V, VI, VII, and VIII contain miscellaneous data for the same centrifuges in the same order, including degradation data wherever it could be calculated for the largest size fraction in the feed. Fig. 1 presents these degradation data in graphical form including extrapolation of the data to the zero-zero point. Fig. 2 shows the relationships existing between the average particle size of the cake products and the average surface moisture content of the same cake products for the various makes of centrifuge. These data and relationships have either been discussed previously or are self explanatory.

Table IX contains basic degradation data for the feed to Carpenter No. 1. The various size fractions are presented in inches and mesh as normally presented, i.e., ⅜ in. x 4-mesh, and in terms of average particle size, in inches. The values contained in col. 4, degradation pct, were obtained from the graph shown in Fig. 1 based on the correlation between the average particle size of a closely sized fraction and degradation or size change in percent. The cake plus effluent size-consist data, col. 5, are presented for comparison with the feed size-consist data, col. 3.

Table X contains the changing size-consist relationships determined for the feed material for Carpenter No. 1 when continually decreasing the top size of the feed.

**Table XI. Carpenter No. 1 Calculated Change in Particle Size Data Based on Size-Consist of Feed**

| Size Mesh* | ⅜x4 Wt, Pct | 4x14 Wt, Pct | 14x48 Wt, Pct | 48x100 Wt, Pct | 100x200 Wt, Pct | —200 Wt, Pct | Totals |
|---|---|---|---|---|---|---|---|
| ⅜x4 | 10.40 | | | | | | 10.40 |
| 4x14 | 5.35 | 36.70 | | | | | 42.05 |
| 14x48 | 3.60 | 6.60 | 28.65 | | | | 38.85 |
| 48x100 | 0.42 | 0.80 | 0.85 | 3.45 | | | 5.52 |
| 100x200 | 0.11 | 0.20 | 0.25 | 0.02 | 1.0 | | 1.58 |
| —200 | 0.12 | 0.20 | 0.25 | 0.03 | | 1.0 | 1.00 |
| Totals | 20.00 | 44.50 | 30.00 | 3.50 | 1.0 | 1.0 | 100.00 |

* Tyler mesh.

Table XI contains data for the calculated changes in particle size for Carpenter No. 1. The ⅜-in. x 4-mesh size distribution shown in col. 2 was calculated as follows:

a—⅜ in. x 4-mesh in feed = 20 pct

b—Degradation of ⅜-in. x 4-mesh size = 48 pct

c—(20) (0.48) = pct of feed degraded = 9.6 pct

d—20-9.6 = 10.4 = pct of ⅜-in. x 4-mesh material left in combined cake plus effluent.

e—(9.6) (0.557) = 5.35 = pct of 4x14-mesh material in the combined cake plus effluent produced in the process of degrading the ⅜-in. x 4-mesh coal.

f—(9.6) (0.375) = 3.60 = pct of 14x48-mesh material in the combined cake plus effluent produced in the process of degrading the ⅜-in. x 4-mesh coal.

g—(9.6) (0.044) = 0.42 = pct of 48x100-mesh material in the combined cake plus effluent produced in the process of degrading the ⅜-in. x 4-mesh coal.

h—(9.6) (0.012) = 0.11 = pct of 100x200-mesh and —200-mesh in the combined cake plus effluent produced in the process of degrading the ⅜-in. x 4-mesh coal.

In the above calculations 9.6 is the pct of degraded material, (0.557) is the pct of 4x14-mesh material

**Table XII. Comparison of Actual and Calculated Size-Consists for Carpenter Centrifuge Combined Cake and Effluent Solids**

| | Carpenter No. 1 | | | Carpenter No. 2 | | |
|---|---|---|---|---|---|---|
| Size Mesh* | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| ⅜x4 | 12.4 | 10.40 | 16.2 | 12.6 | 12.48 | 0.9 |
| 4x14 | 41.8 | 42.05 | 0.6 | 38.0 | 37.60 | 3.7 |
| 14x48 | 35.8 | 38.85 | 8.5 | 34.3 | 36.02 | 5.0 |
| 48x100 | 5.5 | 5.52 | 0.4 | 6.7 | 6.52 | 2.7 |
| 100x200 | 1.8 | 1.58 | 12.2 | 2.5 | 2.21 | 11.6 |
| —200 | 2.7 | 1.00 | 40.7 | 5.9 | 5.17 | 12.4 |
| Avg | | | 13.2 | | | 6.05 |

| | Carpenter No. 3 | | |
|---|---|---|---|
| Size Mesh* | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| 5/16x10 | 50.8 | 50.75 | 0.1 |
| 10x14 | 19.7 | 13.48 | 46.1 |
| 14x48 | 17.5 | 24.14 | 37.9 |
| 48x100 | 7.2 | 8.86 | 23.0 |
| —100 | 4.8 | 2.77 | 42.3 |
| | | | 29.9 |

| | Carpenter No. 5 | | |
|---|---|---|---|
| Size Mesh* | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| 8x10 | 6.72 | 6.74 | 0.3 |
| 10x14 | 12.14 | 11.47 | 5.5 |
| 14x20 | 21.32 | 20.52 | 3.7 |
| 20x28 | 19.09 | 17.11 | 9.3 |
| 28x35 | 14.34 | 14.90 | 3.9 |
| 35x48 | 6.94 | 8.33 | 20.0 |
| 48x60 | 2.56 | 3.42 | 33.6 |
| 60x100 | 4.86 | 6.95 | 43.0 |
| 100x200 | 3.32 | 5.21 | 57.0 |
| —200 | 8.61 | 5.33 | 61.4 |
| Avg | | | 23.8 |

* Tyler mesh.

## Table XIII. Comparison of Actual and Calculated Size-Consists for C.M.I. Centrifuge Combined Cake and Effluent Solids

| C.M.I. No. 1 | | | | C.M.I. No. 3 | | | | C.M.I. No. 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Size Mesh[a] | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct | Size Mesh[b] | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| 6x8 | 3.19 | 3.25 | 1.9 | +¼ | 0.4 | 0.21 | 47.5 | | | |
| 8x10 | 1.62 | 1.93 | 19.1 | ¼x4 | 4.2 | 3.64 | 13.3 | 0.3 | 0.34 | 13.3 |
| 10x14 | 3.73 | 4.37 | 17.2 | 4x8 | 23.0 | 21.83 | 5.1 | 7.3 | 4.28 | 41.6 |
| 14x20 | 14.37 | 10.69 | 25.6 | 8x10 | 10.0 | 13.45 | 34.5 | 10.9 | 6.21 | 43.1 |
| 20x28 | 21.79 | 18.56 | 14.8 | 10x16 | 8.9 | 13.75 | 38.9 | 12.1 | 12.88 | 6.4 |
| 28x35 | 11.98 | 12.15 | 1.4 | 16x20 | 10.6 | 12.21 | 15.2 | 12.7 | 12.03 | 5.3 |
| —35 | 43.32 | 49.05 | 13.2 | 20x30 | 9.8 | 8.76 | 10.6 | 10.4 | 11.35 | 9.1 |
| | | | | 30x40 | 10.3 | 7.94 | 22.9 | 10.8 | 12.16 | 12.6 |
| | | | | 40x50 | 6.5 | 5.45 | 16.1 | 6.7 | 7.31 | 9.1 |
| | | | | 50x60 | 2.2 | 2.41 | 9.5 | 2.5 | 1.95 | 22.0 |
| | | | | 60x100 | 5.4 | 3.78 | 30.0 | 5.9 | 6.95 | 17.8 |
| | | | | 100x200 | 2.4 | 1.90 | 20.8 | 5.2 | 6.44 | 23.8 |
| | | | | —200 | 5.4 | 4.67 | 13.5 | 15.2 | 18.12 | 19.2 |
| Avg | | | 13.3 | | | | 21.4 | | | 18.6 |

[a] Tyler mesh.
[b] U.S. Standard.

in the 4-mesh x 0 fraction as shown in Table X, (0.375) is the pct of 14x48-mesh material in the 4-mesh x 0 fraction, etc. The same method was used to calculate the size distributions shown in cols. 3, 4, 5, and 6 of Table XI. Col. 7 represents the amount of —200-mesh in the original feed. The totals shown in col. 8 were obtained by adding the calculated values shown in cols. 2 through 7.

Tables XII, XIII, XIV, and XV contain actual size-consist data for combined cake plus effluent solids and the calculated size-consist data obtained by the above method of calculation for Carpenter, C.M.I., Bird, and Reineveld centrifuges. A study of the data reveals that there is a good degree of correlation between the actual and calculated size-consists.

### Comparison of Centrifuges

*Degradation Comparison:* If one assumes the size-consist contained in col. 2 of Table XVI as being the feed material dewatered by each of the four centrifuges, then by the previous determined relationships it is possible to calculate the combined cake and effluent solids size-consist data shown in cols. 3 through 7.

By means of the data contained in Table XVI it is possible to compare the four centrifuges on the basis of degradation. The Carpenter, Bird, and Reineveld all show similar degradation characteristics when treating hard structure coals. The C.M.I. used to dewater hard structure coals shows similar degradation characteristics to the Reineveld used to dewater friable coals. For hard structure coals the C.M.I. shows the greatest amount of degradation and the other three centrifuges show lesser and almost identical amounts of degradation.

*Cake Moisture Comparison:* Table XVII and Fig. 3 present degradation information tabulated and plotted in a different fashion. By means of the relationships shown in Fig. 3, it is possible to determine the average size of particle for a centrifuge cake after calculating the combined cake plus effluent average size of particle. Using this relationship and the calculated data contained in Table XVI and the relationships shown in Fig. 2, the following values were obtained:

1—Carpenter cake (hard structure coal)
average particle size = 0.0605 in.
surface moisture content of cake = 7.9 pct

### Table XIII (Continued)

| C.M.I. No. 5 | | | | C.M.I. No. 8 | | | |
|---|---|---|---|---|---|---|---|
| Size Mesh[a] | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct | Size Mesh[a] | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| +¼ | 3.9 | 0.95 | 75.6 | +⅜ | | | |
| ¼x3/16 | 8.3 | 4.66 | 55.0 | ⅜x¼ | 2.6 | 1.0 | 61.5 |
| 3/16x⅛ | 12.6 | 10.73 | 14.9 | ¼x3/16 | 6.6 | 4.01 | 39.3 |
| ⅛x10 | 16.1 | 17.58 | 9.2 | 3/16x⅛ | 9.6 | 8.13 | 15.3 |
| 10x20 | 16.1 | 19.97 | 24.0 | ⅛x10 | 10.9 | 12.35 | 13.3 |
| 20x28 | 6.9 | 9.05 | 31.2 | 10x20 | 15.9 | 16.06 | 1.0 |
| 28x35 | 6.5 | 8.04 | 23.7 | 20x28 | 7.8 | 7.61 | 2.4 |
| 35x65 | 10.1 | 11.58 | 14.7 | 28x48 | 17.7 | 19.05 | 7.6 |
| 65x100 | 4.1 | 4.06 | 1.0 | 48x65 | 8.2 | 10.33 | 26.0 |
| 100x200 | 5.3 | 4.65 | 12.2 | 65x100 | 7.7 | 9.70 | 26.0 |
| —200 | 10.1 | 8.71 | 13.8 | 100x200 | 6.8 | 7.41 | 9.0 |
| | | | | —200 | 6.2 | 4.35 | 29.8 |
| Avg | | | 25.1 | | | | 21.0 |

[a] Tyler mesh.
[b] U.S. Standard.

2—C.M.I. cake (hard structure coal)
average particle size = 0.0565 in.
surface moisture content of cake = 6.85 pct

3—Bird cake (hard structure coal)
average particle size = 0.0535 in.
surface moisture content of cake = 14.50 pct

4—Reineveld cake (hard structure coal)
average particle size = 0.0580 in.
surface moisture content of cake = 7.0 pct

On this basis the C.M.I. and Reineveld centrifuges provide cakes having the lowest surface moisture contents, the Carpenter provides a cake approximately 1 pct higher in surface moisture and the Bird provides a cake having a surface moisture content approximately double that provided by the C.M.I. and Reineveld centrifuges.

*Closed System Moisture Comparison:* However, it is not fair to compare the moisture content of the Bird cake with the cake moistures obtained when using the other makes of centrifuges unless some consideration is given to disposal of the various effluent solids. If one assumes that each of the four centrifuges under discussion is used to provide a dewatered cake and that the effluent solids are thickened and then dewatered by means of vacuum filters and that the centrifuge cake and vacuum filter

### Table XIV. Comparison of Actual and Calculated Size-Consists for Bird Centrifuge Combined Cake and Effluent Solids

| Bird No. 1 | | | |
|---|---|---|---|
| Size Mesh* | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| 4x6 | 15.3 | 15.84 | 3.5 |
| 6x10 | 19.4 | 23.98 | 23.6 |
| 10x14 | 18.7 | 9.58 | 48.7 |
| 14x20 | 10.7 | 9.32 | 12.9 |
| 20x28 | 6.7 | 8.82 | 31.6 |
| 28x35 | 5.3 | 6.19 | 16.8 |
| 35x48 | 3.6 | 7.35 | 104.2 |
| 48x65 | 4.3 | 5.28 | 22.8 |
| 65x100 | 3.6 | 4.28 | 18.9 |
| 100x150 | 2.0 | 2.45 | 22.5 |
| 150x200 | 1.9 | 1.83 | 3.7 |
| —200 | 8.5 | 4.98 | 41.4 |
| Avg | | | 29.2 |

| Bird No. 2 | | | |
|---|---|---|---|
| Size Mesh* | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| 6x10 | 22.3 | 22.34 | 1.8 |
| 10x14 | 14.6 | 16.02 | 9.7 |
| 14x28 | 18.8 | 19.83 | 5.5 |
| 28x48 | 9.1 | 7.22 | 20.7 |
| 48x100 | 7.0 | 5.99 | 14.5 |
| 100x200 | 5.8 | 5.87 | 1.2 |
| —200 | 22.4 | 22.75 | 1.6 |

| Bird No. 3 | | | |
|---|---|---|---|
| Size Mesh* | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| 3x6 | 9.2 | 9.90 | 7.6 |
| 6x10 | 16.3 | 20.86 | 28.0 |
| 10x14 | 9.1 | 10.07 | 10.7 |
| 14x28 | 15.0 | 13.83 | 7.8 |
| 28x48 | 11.8 | 11.99 | 1.9 |
| 48x100 | 7.5 | 6.72 | 10.4 |
| 100x200 | 5.4 | 4.40 | 18.5 |
| —200 | 25.7 | 23.23 | 10.6 |

* Tyler mesh.

### Table XIV (Continued)

| Bird No. 5 | | | | Bird No. 6 | | | |
|---|---|---|---|---|---|---|---|
| Size Mesh* | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct | Size Mesh* | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| ¼x10 | 37.40 | 37.45 | 0.1 | ¼x4 | 14.9 | 14.9 | 0 |
| 10x14 | 8.25 | 12.42 | 50.7 | 4x8 | 27.5 | 28.56 | 3.9 |
| 14x20 | 6.20 | 7.65 | 23.4 | 8x10 | 17.0 | 14.18 | 16.6 |
| 20x28 | 5.10 | 5.94 | 16.4 | 10x20 | 12.5 | 16.09 | 28.7 |
| 28x35 | 4.15 | 4.65 | 10.3 | 20x35 | 6.8 | 8.94 | 31.5 |
| 35x48 | 3.10 | 2.66 | 14.2 | 35x48 | 2.2 | 3.46 | 57.3 |
| 48x65 | 2.50 | 2.20 | 12.0 | 48x65 | 2.05 | 2.88 | 40.5 |
| 65x100 | 2.30 | 1.88 | 18.2 | 65x100 | 2.05 | 2.15 | 4.9 |
| 100x200 | 3.50 | 3.10 | 11.4 | —100 | 15.0 | 8.84 | 41.2 |
| —200 | 27.50 | 22.06 | 19.8 | | | | |
| Avg | | | 17.7 | | | | 25.0 |

* Tyler mesh.

cake are combined insofar as moisture content is concerned, one will have a truer comparison of the various centrifuges from a dewatering standpoint.

Using the information provided in Tables XVI and XVII and the relationships shown graphically in Figs. 3 and 4, it is possible to calculate the average particle size of the centrifuge effluents. For example, the Carpenter combined cake plus effluent (based on the data presented in Table XVI) equals 0.0492 in. average particle size and represents 100 pct. The Carpenter cake from Fig. 3 equals 0.0605 in. average particle size and from Fig. 4 represents 72.5 pct of the combined cake plus effluent. Therefore:

$$(100)\ (0.0492) = (72.5)\ (0.0605) + (27.5)\ (x)$$

$$x = (4.92\text{-}4.39) \div 27.5 = 0.0192 \text{ in.}$$

$x$ = average particle size of Carpenter effluent

By this method of calculation the following effluent average particle sizes were determined: Carpenter = 0.0192 in. (27.5 pct effluent); C.M.I. = 0.0214 in. (52.2 pct effluent); Bird = 0.0005 in. (10.0 pct effluent); Reineveld = 0.0162 in. (18.5 pct effluent).

The effluents from the Carpenter, C.M.I., and Reineveld will provide vacuum filter cakes ranging from 20 to 25 pct surface moisture. The Bird effluent will provide a filter cake ranging from 30 to 35 pct surface moisture. These values are based on results currently being obtained at plants treating

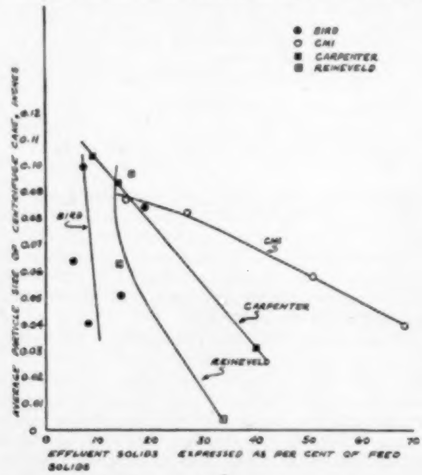


Fig. 4—Relationships existing between average size of dewatered cake solids and the percentage of feed solids reporting to the effluent when dewatering coal by means of centrifuges.

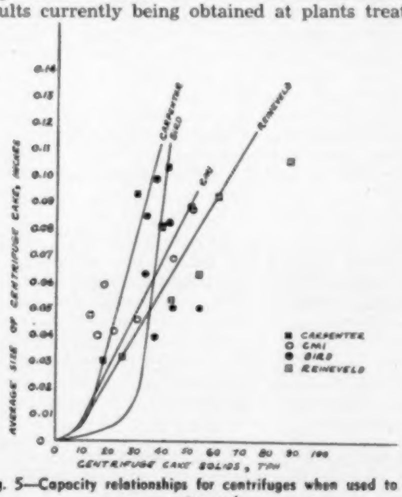


Fig. 5—Capacity relationships for centrifuges when used to dewater coal.

**Table XV. Comparison of Actual and Calculated Size-Consists for Reineveld Centrifuge Combined Cake and Effluent Solids**

| Reineveld No. 3 | | | | Reineveld No. 6 | | | | Reineveld No. 7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Size Mesh[a] | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct | Size Mesh[a] | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct | Size Mesh[a] | Actual Product Wt, Pct | Calc. Product Wt, Pct | Deviation Pct |
| ⅜x5/16 | 2.7 | 2.70 | 0 | ⅜x¼ | 0.11 | 0.11 | 0 | 4x7 | 0.4 | 0.4 | 0 |
| 5/16x¼ | 2.6 | 1.87 | 28.0 | ¼x3 | 7.5 | 4.83 | 35.6 | 7x14 | 10.9 | 8.4 | 22.9 |
| ¼x4 | 4.9 | 5.34 | 9.0 | 3x9 | 16.0 | 15.29 | 4.4 | 14x32 | 35.3 | 32.7 | 7.4 |
| 4x7 | 13.9 | 14.13 | 1.6 | 9x16 | 25.9 | 28.91 | 11.6 | 32x60 | 28.9 | 35.3 | 22.1 |
| 7x9 | 18.2 | 20.06 | 10.2 | 16x32 | 10.9 | 14.48 | 32.8 | 60x100 | 14.7 | 16.4 | 11.6 |
| 9x16 | 16.2 | 22.87 | 41.1 | 32x60 | 12.6 | 8.28 | 34.2 | 100x150 | 2.7 | 3.4 | 25.9 |
| 16x32 | 12.2 | 15.69 | 28.6 | —60 | 26.9 | 28.10 | 4.5 | 150x200 | 1.6 | 1.1 | 31.1 |
| 32x60 | 10.0 | 8.79 | 12.1 | | | | | —200 | 5.2 | 2.3 | 55.7 |
| —60 | 19.3 | 8.55 | 55.7 | | | | | | | | |
| Avg | | | 19.6 | | | | 17.6 | | | | 22.1 |

[a] Tyler mesh.

**Table XVI. Calculated Change in Size-Consist for an Assumed Centrifuge Feed, Based on Degradation Data for Carpenter, C.M.I., Bird, and Reineveld Centrifuges**

| | | Calculated Combined Cake and Effluent Solids | | | | |
|---|---|---|---|---|---|---|
| Size Mesh | Assumed Feed Wt, Pct | Carpenter[a] Wt, Pct | C.M.I.[a] Wt, Pct | Bird[a] Wt, Pct | Reineveld[b] Wt, Pct | Reineveld[a] [c] Wt, Pct |
| 3x6 | 10.1 | 7.07 | 3.53 | 6.06 | 2.9 | 8.5 |
| 6x8 | 12.3 | 10.87 | 7.36 | 10.64 | 5.8 | 10.5 |
| 8x14 | 16.5 | 15.72 | 14.00 | 15.81 | 11.0 | 14.7 |
| 14x28 | 22.3 | 22.98 | 24.07 | 23.40 | 20.4 | 21.2 |
| 28x48 | 14.6 | 15.87 | 18.13 | 16.14 | 18.6 | 15.6 |
| 48x100 | 9.2 | 10.31 | 12.15 | 10.48 | 14.2 | 10.6 |
| 100x200 | 5.5 | 6.25 | 7.51 | 6.36 | 9.2 | 6.7 |
| —200 | 9.5 | 10.93 | 13.25 | 11.11 | 17.9 | 12.2 |
| Average particle size, in. | 0.0567 | 0.0482 | 0.0382 | 0.0472 | 0.0323 | 0.0503 |

[a] Hard structure coals.
[b] Friable structure coal.
[c] These figures are open to question because of the paucity of supporting data but were included because they represent at least a first approximation of the results to be expected.

**Table XVII. Average Particle Size Data for Dewatered Coal or Centrifuge Cake and Composite Cake plus Effluent Solids**

| Centrifuge | Installation Number | Average Size of Cake, In. | Average Size of Combined Cake and Effluent, In. |
|---|---|---|---|
| Carpenter | 1 | 0.0939 | 0.0938 |
| Carpenter | 3 | 0.1043 | 0.1127 |
| Carpenter | 5 | 0.0312 | 0.0241 |
| C.M.I. | 1 | 0.0400 | 0.0351 |
| C.M.I. | 3 | 0.0830 | 0.0675 |
| C.M.I. | 4 | 0.0591 | 0.0399 |
| C.M.I. | 5 | 0.0880 | 0.0761 |
| C.M.I. | 8 | 0.0698 | 0.0629 |
| Bird | 1 | 0.0640 | 0.0601 |
| Bird | 2 | 0.0405 | 0.0364 |
| Bird | 3 | 0.0510 | 0.0342 |
| Bird | 5 | 0.0857 | 0.0698 |
| Bird | 6 | 0.1006 | 0.0623 |
| Reineveld | 3 | 0.0952 | 0.0821 |
| Reineveld | 6 | 0.0597 | 0.0531 |
| Reineveld | 7 | 0.0333 | 0.0265 |

centrifuge effluents or comparably fine slurries by means of vacuum filters.

Then, based on the calculated surface moisture contents previously listed for the various centrifuge cakes and the vacuum filter cake moistures listed above, the following combined cake moistures were calculated. These cake moistures are based on hard structure coals. 1—Carpenter combined cake = 11.50 pct surface moisture, 2—C.M.I. combined cake = 13.70 pct surface moisture, 3—Bird combined cake = 16.55 pct surface moisture, 4—Reineveld combined cake = 9.86 pct surface moisture.

On this basis the Reineveld centrifuge, in combination with a vacuum filter, provides the lowest moisture content product. It must be remembered, however, that the Reineveld calculations for hard structure coals are based on very sketchy data.

*Capacity Comparison:* Fig. 5 shows the relationships existing between the average particle size of the cake and the tonnage of cake produced for the four makes of centrifuges. By means of these relationships it is possible to determine the tonnage that each make of centrifuge could handle when dewatering coal of the size-consist presented in col. 2 of Table XVI. These tonnages are as follows: Carpenter = 25.5 tons per hr of cake; C.M.I. = 34.0 tons per hr of cake; Bird = 36.0 tons per hr of cake; Reineveld = 40.0 tons per hr of cake. The Reineveld centrifuge has the greatest capacity, the C.M.I. and Bird are nearly equivalent to each other but have less capacity than the Reineveld, and the Carpenter has the lowest capacity.

## Conclusions

It should be emphasized that these results are based on one set of assumed conditions. Because of the number of variables involved it would be dangerous to draw any general conclusions. Each dewatering problem will require a separate analysis and undoubtedly will lead to an individual conclusion.


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## References


[1] O. R. Lyons: Methods and Equipment for Dewatering and Drying Washed Coal. Coal Mine Modernization, 1949 Year Book, American Mining Congress.

[2] P. Rosin and E. Rammler: Laws Governing the Fineness of Powdered Coal. *Journal* Inst. of Fuel (1933) **7**, pp. 29-36.

[3] J. G. Bennett: Broken Coal, *Journal* Inst. of Fuel (1936) **10**, pp. 22-39.

[4] M. R. Geer and H. F. Yancey: Expression and Interpretation of the Size Composition of Coal. *Trans.* AIME (1938) **130**, pp. 250-269.

[5] O. R. Lyons: Dewatering and Thermal Drying. *Coal Preparation*, 2nd Edition, Chapter 19, pp. 656-657 (1950), AIME.

# Factors Influencing the Choice of a Loading Machine

by Donald W. Mitchell

MINE operators have a choice of several classifications of mechanical loaders. Within each classification there are many types and makes available. Table I lists loaders on which manufacturing data as to operating characteristics are available. This paper discusses the conditions met in a mine as they affect these characteristics.

It is assumed that management will provide satisfactory engineering, supervision, power, maintenance, loader service within a concentration of workings, and a balanced working cycle served by balanced production equipment. These are factors which affect the optimum operational efficiency of a loader. The conditions which determine loader choice are:

**Height of Vein**—The main limitation to the use of a loading machine is the height to which the vein is mined; i.e. a loader cannot be higher than the place in which it is to work unless rock is taken. Since there are several low vein loaders being developed and successfully applied, this does not appear to be a requisite of an efficient mining operation.

The maximum useable height of a loader should be equal to the working seam thickness less a working clearance for travel and operation.

A—Working seam thickness =

B—Artificial roof support thickness =

C—Safe headroom below support = (generally about 6 in.)

D—Height of roadway =

E—Total of B + C + D =

A—E = maximum loader height

F—Distance from top of roadway to bottom of roof support =

G—Height of loader's coal or ore line (see Table I) =

H—Difference between F and G = Size of largest broken particle + a safety factor of 2 to 3 in.

H is a loadability factor and is important because the clearance over the top of the conveyor chain to the roof or roof support must be greater than the largest broken particle or else the particle and/or the conveyor chain may be broken. From this standpoint it might be desirable to use a lower height machine even though it may have a smaller capacity, though this is warranted only when increased lump realization offsets lower man-day and machine production rates. Ivan Given has stated, "Loading should not be handicapped by securing lump only to grind it in the breaker."

**Width of Working Place**—The width of a working place is the greatest width a place may be safely driven. The working place includes not only the face but the roads the loader must tram when mucking out more than one face. The width is limited by the system of placing props with sufficient room between them for the machine runner (about 2 ft).

Maximum width of place in which the loader will operate at maximum efficiency is determined by the type of mounting. With track-mounted loaders, maximum width of place is determined by maximum angular swing of the loading head and proximity of track to the face. The use of double track leads to added expense and operational complexities. Several mines that have used double-track systems have found that a substantial saving is made by the use of machines that load out wider places. Trackless loaders may work in rooms of any maximum width.

Minimum width of place in which a loader will operate is determined by width of the loader plus a safe movement area for the operator. Often a barodynamic study of the mine will show that either an increase in room width and/or a change in the system of propping may be made by using roof bolting, full or part-width room timbers, removable aluminum I-beams at the face, etc. Increasing the width of a working place will, in general, increase loader operating efficiency by providing more material per fall and by decreasing the preparation and moving time per ton. A change in the system of propping that would increase the minimum width might permit the use of a higher capacity loader with safer working conditions. Proper face timbering is necessary to insure safety from roof falls and because the speed of preparation and loading generally increases since the men work with greater assurance and there is less chance of kicking out posts.

**Maximum Room Length**—With the exception of the scraper and the duckbill, the limit to room

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length behind the loader is determined by the method of conveyance. Studies by R. W. Thomas and A. E. Schneider indicate that a scraper loses its efficiency when travelling distances greater than 75 to 100 ft since more time is spent conveying than is spent loading, and as the length increases, the time ratio doubles. The maximum length of a shaker pan line with a modern drive is about 400 ft. The experience of most operators has been that the addition of a loading head, swivels, bell-cranks, etc. will, by their added load to the drive, decrease this maximum length to about 250 or 300 ft.

**Bottom Characteristics and Minimum Bearing Strength**—The bearing strength and characteristics of the mine floor determine whether a track or trackless type loader may be used.

The scraper requires a hard bottom otherwise it will dig itself in, with the possibility of breaking the runway, increasing the load on the hoist, and contaminating the loaded material with bottom rock. Sharp humps and swags will also interfere considerably with scraper operations.

The duckbill requires a hard, relatively smooth bottom. Soft bottom makes the loading head movement sluggish, which in turn slows down or stops the movement of the material in the pan line; a hump or swag stops the head and/or takes it off the floor and away from the pile.

Almost all mine bottoms have greater bearing strengths than the minimums shown; however, as seen, the characteristics of the bottom influence the choice of mounting considerably. The use of track-mounted machines for loading and other mine operations protects soft bottom and avoids excessive contamination of the material and easily passes over humps and swags.

**Material Handled and Particle Size**—In the past, hard and sticky ores have relegated mechanical loaders to the shovel, shaker, and scraper types. Today, most mobile type loading machine manufacturers should be able to supply their loaders with wearing parts hardened and readily replaceable, with conveyor flights that hug the deck and sweep it clean. The abrasive characteristics of the material to be handled affects loader choice because of the maintenance problems and costs involved. Many coal operators have reported high maintenance costs caused by excessive part wearing. Since coal is not an abrasive and most of it acts like graphite and lubricates, this wearing may be attributed to the commonly associated impurities within the coal seam which are moderately abrasive and hard. When purchasing a loader for a particularly dirty seam, the coal operator, like the hard rock man, should specify that the machine be adapted to handle these abrasives successfully.

The minimum size particle handled by most loaders is dust. When mining in dusty conditions, machine specifications should provide for adequate seals to keep out the dust and to preserve efficient lubrication.

The maximum size particle handled depends upon the dipper or gathering arm dimensions, see Table I. For minimum degradation this dimension should be large in comparison with the size of particle loaded. When loading large particles, protection against overloading by slip clutches is preferred to shear pins, in the writer's experience. It is realized that these specifications would increase the loader's first cost, but they should provide lower maintenance and repair costs with higher tonnage realization for the machine.

**Maximum Positive and Negative Grades**—Pitches encountered in a mine will affect loader choice because one machine will not perform as well as another on certain grades. Maximum grades, as shown in Table I, may affect a mobile loader's capacity by about 25 pct, although actual tonnage mined is dependent upon the ability of the conveying unit to operate on the grade, which may result in negligible production rates.

Scrapers do not lose their capacity when operating on adverse grades when heavier hoisting and power facilities are provided. The duckbill on a positive grade almost doubles its capacity since the material will slide down the pan line; on negative grades the capacity is decreased about one third.

**Side Pitch**—Scrapers are not affected by side pitch when the runway is to the dip. Track-mounted loaders are not affected when level track is maintained, nor is the duckbill when the pan line is kept level or side boards are attached. The side pitch on which the other types of loaders will operate is shown in Table I; their capacity is decreased up to about 25 pct when operating on a side pitch.

**Capacity**—Most of the loaders in the table show manufacturers' rated capacities per minute and per 7 hr of productive working shift. Tonnage figures followed by question marks are estimations. The figures on the best tonnage reported from the field show what the machine has done. They should not be construed as being indicative of maximum capacity since few operations have as yet been developed where actual loading is more than 40 pct of the productive shift time.

To meet a loader's rated capacity, sufficient tonnage must be made available (with minimum face maneuvering), and transportation must be provided at such a rate as to remove this loaded material with minimum delay. Capacity is also dependent upon effective fragmentation and the method of laying down the broken material in a close but not tight pile.

**Track vs Trackless Considerations**—When determining whether to use a track or a trackless type loader, it is necessary to study the natural conditions under which the machine is expected to work.

Track-mounted and rubber-tired loaders have faster tramming speeds than the caterpillar types, and where operations are between places far apart, they are preferred.

One of the primary advantages of the trackless type loader is that it may be operated in a place of any width (greater than minimum) while track-mounted loaders, in places wider than shown in the table, require the use of double track and switches.

With track-mounted loaders the width of working face is limited to the swing of the head, loading at extreme angles is not as effective as loading directly in front of the machine. The trackless loader attacks the pile with pick-like blows rather than with the scraper or shovel effect used by the more popular types of track-mounted loaders. The trackless loader's weight is directly behind the force of the attack while the track-mounted loading mechanism is subjected to an angular force while loading or digging either side of center. In robbing and in side slabbing pillars the trackless loader has the advantage from the standpoint of spotting the conveying unit and attacking the material.

Trackless loaders are more suited to pitching areas

## Table I. Loading Machine Factors

| Loading Machine | Height of Loader In. | Height of Coal or Ore Line, In. | Material Handled Besides Coal | Maximum Particle Size | Min. Operating Width, Ft | Max. Operating Width, Ft | Min. Bearing Strength of Bottom | Mounting | Max. Operating Grades, Degrees |
|---|---|---|---|---|---|---|---|---|---|
| Scraper | any | any | any | varies | 5 | any | hard | none | any |
| Duckbill E Goodman | 25 | 24 | any | 20x20x60 in. | 4 1/6 | 50 | hard | none | +any-5 |
| Clarkson 24 BB | 28 | 24 | not rec. | 1 ton | 10 | 22 | 30-lb track | track | ±17 |
| Joy 12 BU | 28¾ | 24 | | 12 in. | 6 | any | 1257 psf | cats. | ±10 |
| Goodman 660 BA | 31 | 22 | | 36x24x18 in. | 8⅝ | any | 4000 psf | cats. | ±5 |
| Jeffrey L-500 | 31 | 25 | not rec. | r.o.m. | 9 | 27 | 30-lb track | track | ±5 |
| Joy 14 BU-7A | 31⅛ | 25 | | 24 in. | 7⅓ | any | 2126 psf | cats. | ±10 |
| Myers-Whaley Automat low | 40½ | 36 | any | 30 in. | 8 | 24 | 40-lb track | track | ±4 |
| Goodman 360 | 41 | 32 | any | 36x24x18 in. | 7½ | 24 | 40-lb track | track | ±5 |
| Joy 8 BU Low Ped. | 41 | 35 | | 18 in. | 7 | any | 2360 psf | cats. | ±12 |
| Clarkson 28 FA | 42 | 36 | not rec. | 1 ton | 10 | any | 2000 psf | rubber-tired | ±10 |
| Joy 7 BU | 43 | 37 | | 24 in. | 7⅛ | any | 4770 psf | cats. | ±10 |
| Myers-Whaley Automat No. 3 | 44½ | 38 | any | 30 in. | 8 | 24 | 40-lb track | track | ±4 |
| Goodman 460 | 46 | 34 | any | 36x24x18 in. | 7½ | 26½ | 40-lb track | track | ±5 |
| Jeffrey L-600 | 46¾ | 37 | not rec. | r.o.m. | 9 | 28 | 40-lb track | track | ±5 |
| Joy 11 BU | 53 | 43 | | 24 in. | 10 | any | 3820 psf | cats. | ±10 |
| Sullivan Lohite | 54 | 54 | any | 42 in. | 5 | any | 30-lb track | track | any |
| Eimco 12 B Rockershovel | 72 | 72 | any | 30 in. | 5 | 8+ | 20-lb track | track | +5-30 |
| Joy HL 3 Shovel Loader | 75 | 75 | any | | 3 5/6 | 7 | 20-lb track | track | ±12 |
| Gardner-Denver 9 | 76 | 76 | any | | 5¼ | 7¾ | 20-lb track | track | +5-10 |
| Joy 18 HR-2 | 84 | | any | 24 in. | 10 | any | 3200 psf | cats. | ±10 |
| Eimco 21 RS | 85 | 85 | any | 36 in. | 6 | 10 | 25-lb track | track | +5-30 |
| Joy HL 20 SL | 88 | | any | | 4 1/6 | 9 | 30-lb track | track | ±12 |
| Gardner-Denver 9H and L | 79-88 | | any | | 5¼ | 7¾-8½ | 20-lb track | track | +5-10 |
| Goodman Conway 125 | 84-91 | | any | | 5 2/3 | 14 | 40-lb track | track | ±4 |
| Gardner-Denver 114 and 14 H | 91-97 | | any | | 6½ | 7¾ | 30-lb track | track | +5-10 |
| Eimco 40 RS | 94 | | any | 36 in. | 8 | 12 | 30-lb track | track | +5-8 |
| Goodman Conway 50B | 106-116 | | any | 20 in. | 6 | 14 1/3 | 40-lb track | track | ±4 |
| Goodman Conway 100 | 144 | | any | 20 in. | 6½ | 20 | 60-lb track | track | ±4 |

because they work on steeper grades with less loss to capacity than track-mounted types. Where side pitches occur, the difficulty and expense incurred in laying out and maintaining level track is negated by the use of a trackless loader.

Where abrupt rolls occur frequently, unless good roadway is maintained, hand-loading onto conveyors appears to be the only method available to the operator today. This is one of the few conditions where hand-loading must supercede mechanization. The development of a loading mechanism to work off a chain conveyor might profitably be studied.

If the top conditions are such that close timbering and narrow entries are required, it is more difficult for the trackless than for the track-mounted loader to negotiate turns or to tram with any degree of mobility. Then too, the machine runner may be squeezed against a post and/or the post may be knocked out by a sudden side-kick. Here the use of track maintains proper and accurate man and equipment clearance.

The operators of all loaders under a height of 54 in. are a safe distance from the loading head if timbering is securely stood close to the face prior to firing the cut (see column Operating Distance to the Head in Table). Since to load out the cut the entire trackless type loader must move, a track-mounted loader might be considered safer to use under tender and heavily propped roof because only the loading head need be moved to load out the face, thus lessening the possibility of knocking out props.

In some beds trackless units working directly on the bottom might break it up, increasing contamination of the loaded material. This tendency is decreased by the use of track-mounted loaders.

In very wet and muddy sections trackless loaders have been successfully used but with large non-operating delays and with greater power consumptions. It is a matter of economics as to whether or not road maintenance will be able to pay for itself from the advantages obtained through the use of trackless units (wider rooms, higher total loading capacity, elimination of tracks and switches, etc.). Firmer traction to overcome the disadvantages of a soft bottom may be attained by "corduroying" roads (laying down straw, waste timber slabs, planking or broken refuse). Where coal is of sufficient height, about 4 in. of coal left over a bad bottom generally has made an excellent roadway for trackless equipment. But for any trackless roadway, better than good maintenance is required.

A. L. Toenges[1] has shown that with gathering haulage, rail and rubber-tired, labor costs for rubber-tired systems are less for units of the same size and traveling the same distance when track costs are included in the costs of rail-gathering systems.

The maneuverability and flexibility of the trackless loader especially adapts it to old working areas. Their use often results in substantial savings realized through the use of a natural roadway.

A saving of 10 lb or more of rail per yard may be achieved in a section using trackless type equipment with gathering motors since rail weight is then dependent upon the weight of the locomotive. Where track-mounted face equipment is used, rail weight is usually based upon the weight of the heavier loader or cutter.

With track, the cost involved in labor and supplies is not the only determining factor. When it is not used at the working places, many delays that result in scheduling the operation (conjunctive movement of drilling, cutting, conveying, gathering and loading machines) are eliminated. Because of the shorter switching interval at the face, the trackless loader

## Table I. (Continued)

| Loading Machine | Max. Side Pitch, Degrees | Operating Distance to Head, Ft | Rated Capacity, Tons per Min. | Max. Rated Capacity for 7 hr | Best Reported Field Shift | Power Source Used | Average Hp Demand | Repair Parts, Cost per Ton, c | Carry or Throw of Ore |
|---|---|---|---|---|---|---|---|---|---|
| Scraper | any | varies | varies | varies | 130 (2y.) | dc, ac, air | varies | low | C |
| Duckbill E Goodman | 15 | varies | 1 | 400 | 400 | dc, ac | 10 | low | C |
| Clarkson 24 BB | 5 | 16 | 8-10 | 4-600 | 750 | dc, ac, air | 32 | 2 | C |
| Joy 12 BU | 8 | 8 | ¾ | 315(?) | | dc, ac | 7 | 2 up | C |
| Goodman 660 BA | | 10+ | 4(?) | 1800 | 1466 | dc, ac | | | C |
| Jeffrey L-500 | on track | 10+ | 3 | 1200(?) | | dc, ac | | | C |
| Joy 14 Bu-7A | 8 | 11 | 5 | 2000(?) | | dc, ac | 15 | 2 up | C |
| Myers-Whaley Automat low | 5 | 12½ | 3 | 700 | 766 | dc, ac, air | 25 | 2 | C |
| Goodman 360 | 3½ | 11½ | 4(?) | 1600 | 1030 | dc, ac | | | C |
| Joy 8 BU Low Ped. | 10 | 7 | 1½ | 630(?) | | dc, ac, air | 15 | 2 up | C |
| Clarkson 28 FA | 3 | 15 | 8 | 5-600 | 650 | dc, ac, air | 32 | 1 | C |
| Joy 7 BU | 8* | 10 | 2 | 800(?) | | dc, ac | 17-22 | 2 up | C |
| Myers-Whaley Automat No. 3 | 5 | 10½ | 3 | 700 | 766 | dc, ac, air | 25 | 2 | C |
| Goodman 460 | 3+ | 10½ | | 1600 | 1030 | dc, ac | | | C |
| Jeffrey L-600 | | 20‡ | 2 | 1200(?) | 600 | dc, ac | 40 | | C |
| Joy 11 BU | 8 | 10 | 4 | 1000(?) | | dc, ac | 25-30 | 2 up | C |
| Sullivan Lohite | any | varies | varies | varies | | dc, ac, air | 15 | low | C |
| Eimco 12 B Rockershovel | on track | 2 | 20 cfm | 8400 c.f. | 250 tons | dc, ac, air | 12 | 1 | T |
| Joy HL 3 Shovel Loader | on track | 2 | | | 100 tons | air | 8 | 5 | T |
| Gardner-Denver 9 | on track | 2 | 1 | | 420 | air | 15 | | T |
| Joy 18 HR-2 | 8 | | 6 | 2520 | | dc, ac | 25-30 | | C |
| Eimco 21 RS | on track | 2 | 35 cfm | 14700 | 350 tons | dc, ac, air | 20 | 0.8 | T |
| Joy HL 20 SL | on track | 2 | | | 150 tons | air | 15 | 5 | T |
| Gardner-Denver 9H and L | on track | 2 | 1 | 420 | | air | 15 | | T |
| Goodman-Conway 125 | on track | 4 | 63 cfm | | | dc, ac | 25 | | C |
| Gardner-Denver 114 and 14 H | on track | 2 | 2 | 840 | | air | 15 | | T |
| Eimco 40 RS | on track | 4 | 60 cfm | 25200 | 400 tons | dc, ac, air | 40 | | C |
| Goodman Conway 50B | on track | 4 | 81 cfm | | | dc, ac | 50 | | C |
| Goodman Conway 100 | on track | 4 | 135 cfm | 2365 | | dc, ac | | | T |

often has a higher total loading capacity.

The advantages of a scraper over other types of mechanical loaders are: lower first cost, lower maintenance charges, greater mobility and flexibility, and operator is a great distance from the face.

Where bottom conditions are bad, power shovels are preferred for the reasons previously mentioned. S. S. Clark states, "In areas where the broken rock is scattered (wide openings) power shovels require numerous tracks, and the time lost in switching negates the high loading capacity of these machines. In very high ground the danger of rock slides due to undercutting the broken pile of rock with the power shovel is always present. The slusher type starts cleaning out the breast, so that in a short time the drills are ready to set up, which is a definite advantage where mineable areas are limited."[10] Two manufacturers have developed caterpillar-mounted rock loaders which should find wide use in those mines that have been unable to use other types of power shovels.

A. E. Schneider has stated,[2] "Our studies indicate that up to 100 feet the capacity of the slushing machine is about that of a shaker, but beyond 100 feet the capacity of the slushing machine gradually drops due to the additional time for travel of the scraper in both directions, while the shaker has the same capacity per hour regardless of its length." R. W. Thomas[4] has estimated through experience and experimentation that 75 ft is the maximum efficient distance of haul for a scraper as compared to a shaker. This brings to notice the importance of: (1) making this comparison between a scraper and a power-shovel, (2) the development of a duckbill-type loader that could be used successfully in the metal mines to replace the scraper.

Since both the scraper and the duckbill shaker require rather similar bottom and face top conditions for efficient operation, the factors influencing the choice between them are: 1—First cost (which generally favors the scraper), 2—positive grade (which generally favors the duckbill), 3—negative grade (which favors the scraper), 4—width of working place (which favors the scraper in widths greater than 50 ft), and 5—distance of travel from the face to the main conveying unit (as discussed above).

**Carry or Throw of Ore**—As seen in Table I, some loaders carry the ore by conveyors to the conveying unit, while others throw the ore into the unit. The main disadvantages of throwing the ore are: 1—The shock to the conveying unit which thereby limits the types of conveying units that may be used. Several mining authorities believe that a measure of the efficiency of a mining method is the ability of the method to provide for the moving of large quantities of material of large fragmented sizes with the least shock to the equipment, 2—degradation, which is primarily of interest only to the coal miner.

The main advantage of the loader that throws rather than carries the ore is that it is less expensive in both first cost and in maintenance. It has fewer moving parts and greater simplicity of design.

**Power Requirements**—Table I shows what type of power may be used with the various loaders. The high horsepower demand of certain loaders is not an important factor affecting their choice except in those cases where peak demand approximates average demand and power costs would be considerably increased by the use of high demand equipment.

For a long period of time, mechanical loading of coal has been accomplished largely by the use of dc machines, probably as a result of the use of old type and variable speed equipment. Most ore-mining equipment has been powered by compressed air

probably because the air was already at the working face for the operation of drills, and it was assumed to be easier and cheaper to attach the air hose to the loading mechanism than to install special power cables.

Since most mines using dc power convert this from an ac source, one might raise the question as to why direct-current is used except on that equipment, such as locomotives and hoists, which requires variable speed motors. In a section, with the exception of track haulage, all loaders and auxiliary equipment might be powered easily with ac instead of dc motors, and, according to George C. Barnes, Jr.[5] definite advantages may be shown with respect to "(a) first cost, (b) maintenance, (c) total operating cost, (d) flexibility, (e) efficiency, (f) safety.

"A fair estimate of cost for a complete a-c system for a given mechanized mining section, including equipment to transform 2300 volts or more primary to useable underground voltages, circuits, motors and controls, is somewhere near 50 percent of the cost involved in installation of a comparable d-c system."

Air-driven motors have certain advantages in poorly ventilated sections of hot mines in that the exhaust air furnishes some measure of relief from uncomfortable working conditions. In gaseous mines, or in those mines where dust is combustible, compressed air has obvious advantages from the standpoint of safety.

In distant sections already furnished with compressed air and where long power lines would have to be run solely for the purpose of operating a loading machine, the air-driven motor has the advantages of lower installation costs. One of the primary objections to air-driven loaders is its utilization of power provided and needed for other purposes, this factor must be considered when deriving cost figures.

In operation, the air motor when overloaded will stall without damage, but conversely it will not provide the momentary excess power that may be needed to dig out heavy material or to overcome other obstacles. Electric motors that are not fully protected may be damaged by too frequent and prolonged overloading. Some operators who have replaced air-driven loaders with electrically operated units report lower operating and maintenance costs.

Robert C. Matson[6] has presented figures showing actual comparative costs of scraping for electric and air-operated hoists. The average shows that electric power costs per ton had a favorable ratio of about 8 to 1 as compared to similar air-operations.

It requires, theoretically, about 4 hp at the compressor to deliver 1 hp of useful work to the air-operated motor, without allowances for leakage in air lines, etc. In other words, direct electric drive will consume about 25 pct as much power to do the same amount of work as an air-drive.

**Maintenance**—Simplicity of design and accessibility of parts for repair and lubrication are of major importance in the choice of a loader. Unfortunately, no data comparing these points on all loaders are available to the writer. Maintenance cost figures may serve as a basis of comparison but cannot be considered reliable since the figures gathered appear to be calculated by varying methods. Loaders, such as the scraper and the duckbill, by their comparative simplicity, will be cheaper to maintain than other types of loaders. It may be reasoned that caterpillar and rubber-tired loaders should be less expensive to maintain than track-mounted units since they are of simpler construction with fewer moving parts. It is hoped that a concentrated study of maintenance problems and costs relative to the individual loaders may be made in the near future.

**Availability of Parts**—Some mines are located in regions that are not serviced readily by some loading machine manufacturers. The use of a loader would seriously hamper operations when fast service and delivery of normally unstocked parts is not available.

**Table I**—In most cases, after studying the conditions that affect the choice of a loader, the operator will have decided that one machine best meets his needs. When no decision has been made on this basis, the following points might be considered:

1—The tonnage that the loader will be required to load per shift based on the ability of the mine to provide and to remove this tonnage with minimum delay. An example: If the mining facilities (preparation at the face and outside, hoisting, etc.) are capable of taking 100 tons per hr from one loading machine section, it would be preferable to provide one loader with a 150-ton capacity rather than one which would load 300 tons per hr or two which would load 75 tons per hr.

2—If mining conditions are such that a mining method cannot be devised that would approach this condition of maximum efficiency, then the loader should be given a number of nearby places to load out.

3—As the time spent in moving from place to place increases (if the loader must wait for a place to be prepared, increase the number of places or the speed of preparation rather than decrease the loading rate), the tonnage demand on the loader is increased and a loader with its complimentary equipment of higher rated capacities is required.

4—Where mining conditions are such that the use of several different types and makes of loaders would result in high individual loader performance in sections of the mine, thought must be given to the increased complexity of providing repairs and parts, and to the difficulty of placing any loader in any part of the mine. It might be advisable for the average operator to use as few variations in makes and types as vein conditions permit.

Studies show that the maintenance cost for most loaders, mainly coal types, is about 33 pct to 50 pct the loader operating cost per ton mined. Standardization generally decreases maintenance costs, which in turn results in a decreased cost per ton mined. Although there is no reason to believe that standardization should decrease tonnage substantially, it might result in a long term increase.

## References


[1] U. S. Bureau of Mines, Rept. of Investigations 3519, 3577.

[2] S. S. Clark: Eagle-Picher Tri-State Mining Methods. *Engineering and Mining Journal*. (November 1943).

[3] A. E. Schneider: Mining and Conveying Underground Ore. Seventh Annual Mining Symposium, Duluth, Minn., January 1946.

[4] R. W. Thomas: Shaker Conveyors for Block Caving. *Mining Congress Journal*. (December 1946).

[5] G. C. Barnes, Jr.: A Case for A-C Mining. *Mechanization* (March 1950).

[6] R. C. Matson: Scraping Practices in the Michigan Iron Mines of the Lake Superior District. Michigan College of Mining and Technology, *Bull.* 4, 2 (1929).

# Primary and Secondary Mining with Auger Equipment

by D. M. Bondurant

**Auger mining—extraction of coal with large diameter augers—is proving profitable in recovering coal left after stripping has ceased to be economical. Its many advantages—low initial cost of equipment, low operating cost, low power demand, adaptability to selective mining, simplicity of operation, etc.—have excited the interest of some in the industry in its possibilities for underground operation.**

At the present time, the coal industry is greatly interested in any method or machine that will cut the cost of producing a ton of coal, while at the same time producing a product of quality and grade suitable to the customer.

Comparatively new and, as yet, little known, auger mining is proving a profitable method of coal recovery. It may be used for the production of low-cost, high-quality coal with equal success from both the hard-to-mine seams, those with banded impurities and bad roof conditions, and the more easily mined seams as classified according to conventional mining methods.

A number of units are now in operation and production information is available that should be of particular interest to coal operators and of general interest to anyone associated with the coal-mining industry.

Auger mining refers to coal extraction with large size augers capable of drilling to great depths and having a high capacity. Consideration of the equipment and methods used in drilling an ordinary shot-hole will give a picture of auger mining on a smaller scale.

At present, auger mining is used largely for recovery of coal from the highwall after strip mining becomes uneconomical because of the type and the thickness of the overburden which must be moved.

Coal augers have many of the advantages of present continuous mining machines, along with many more. The four distinct operations of conventional mining—cutting, drilling, shooting, and loading—are eliminated and replaced by the combined operation of boring and conveying of the coal.

The coal recovery auger is an adaptation of the horizontal rock drill used for drilling shot-holes to shatter and loosen overburden in strip mining operations. During the war the Becker County Sand and Gravel Co. of Summersville, W. Va., experimented with drilling coal with 6 and 9-in. rock augers. The results led to the successive development of the 20, 24, 30 and the 36-in. machines, the latter having appeared in the coal fields within the past six months.

Because of the great success of the smaller size

Fig. 1—Typical augering operation. Core breaker head in foreground for 30-in. auger.

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Fig. 2—Using 36-in. auger in 84-in. Eagle seam at Kingston, W. Va.

augers, it is logical to presume that larger units will be forthcoming from the commercial source.

Several manufacturers have been experimenting with and are now manufacturing machines that will bore holes up to 36 in. diam. The several machines are essentially the same except for detail construction of the drive unit, see Fig. 1.

The drill heads are of two types: the standard, and the core breaker. The standard, or slack type head, as it is called in the field, produces slack coal. It consists of a pilot cutter extending several inches ahead of three main cutter arms. Between the pilot cutter and the three main cutter arms, three stub cutter arms enlarge the hole cut by the pilot cutter. Thirty-two replaceable, chisel point, borium-tipped bits are used in each standard type head.

The core breaker head, or "lump head," consists of a steel barrel of auger diameter around which carbide tipped bits are spaced. As the barrel rotates, these bits cut a circular kerf coring out the coal. Preceding the cutting edge of the barrel by a few inches, a pilot cutter similar to the one on the standard head cuts a center hole around which the core is to be formed. Following the pilot cutter, a tapered burster follows into the center hole, breaking the core to the circular kerf, producing variable size lump—occasionally as large as the diameter of the core barrel. The position and degree of taper of the burster governs the amount and size of lump produced.

Auger sections are 6 ft long and serve to transmit power from the drive to the drilling head and at the same time convey the broken coal to the mouth of the opening.

The drive unit consists of a main frame and power unit. For recovery of coal after strip mining, the power unit generally is gasoline driven, although diesel and electric motors are optional. The power unit rotates the auger mechanically through a clutch and transmission gearing.

Forward motion is provided by a hydraulic unit which causes the power unit to travel forward and backward on the main frame a distance of approximately 8 ft. This provides ample space for attaching the next auger section. The same motor operates the hydraulic unit.

Jacks and spuds are mounted at each corner of the main frame for holding the machine against the thrust of the auger and for leveling and vertical aligning the machine.

### Highwall Operation

The machine is placed at right angles to the general trend of the highwall, with the front end far enough out to clear the first auger section and drill head, see Fig. 2. The jacks are set so that the slope of the main frame, in the direction in which the hole is to be bored, coincides with the slope of the seam. Perpendicular to the line of drilling, the machine is set level. The setting of the machine with the slope of the coal is done largely by guesswork, which at times results in the boring of short-depth holes. The writer suggests that a clinometer be used to expedite setting the slope of the machine and that the back of the hole be inspected periodically for any necessary adjustment of the clinometer reading.

The coal seam, or that part of the seam being bored, should be at least 6 or 8 in. higher than the auger diameter to allow for any vertical movement of the auger, local rolls in the seam, and rotational wobble, which generally accounts for a hole diameter of 1½ to 2½ in. greater than the auger diameter.

To start operations, the drill head and one auger section are attached and the pilot cutter is started into the coal in reverse rotation to keep the cutter from wandering. As soon as the pilot cutter has a good start, the drilling is continued in second gear. The speed and feed vary with the hardness and structure of the coal. With a 24-in. auger, medium-hard coal should drill at 60 rpm with a feed of ¾ in. per revolution.

Directional control can be governed to some extent by the rate of feed. Heavy-feed pressure tends to force the head up while a light feed tends to lower it. All holes lead to the right as a result of the clockwise rotation of the auger. The lump head has better directional stability than the slack head.

After a hole has been completed, the string of auger sections is left stored in the hole and retrieved as required. Whenever a section is needed, the entire string is pulled out 6 ft by a retriever arm and chain as the drive unit is run in reverse on the frame to

Fig. 3—Tail end drive, elevating belt conveyor, 16-in. auger in 25-in. Blue Gem seam at Barboursville, Ky.

Fig. 4—Car of lump Sewell coal produced with a 30-in. core breaker head, Winona, W. Va.

permit attachment of the retrieved section. This necessitates the use of two drill heads. Time is saved, however, because rehandling of the augers is not necessary. Also, no augers are lying in the way in the limited space between the highwall and spoil.

The coal is deposited at the mouth of the opening onto a portable elevating conveyor, which conveys the coal up into a truck, as shown in Fig. 3. The conveyors are powered by small two-cylinder gasoline engines. When boring near the floor of the coal seam, it is necessary to dig out enough of the floor material to provide clearance between the tail end of the conveyor and the auger flights.

Care must be taken to bore all holes parallel. Cutting into another hole tends to bind the augers, causing breakage and bending. Alignment stakes should be set for each new setup.

The present machines are moved to new positions by skidding on greased rails. It is anticipated that future development will provide a self-propelled machine, making positioning of the unit an easy and less time-consuming job.

## Hole Depth

The depth of hole is dependent on the power of the drive unit, the ability of the auger sections to resist the high torques encountered, local conditions in the seam and experience of the operator.

Since most operations at the present time are mining pillar coal left between the strip pit and old underground workings, it is hard to determine the maximum depth of holes that can be drilled. The standard length of auger proposed for the machines by one manufacturer is 60 ft. The following are maximum lengths some augers are drilling.

| Auger Size, In. | Motor, Hp | Hole Depth, Ft |
|---|---|---|
| 16 | 60 | 96 |
| 24 | 60 | 108 |
| 24 | 95 | 120 |
| 30 | 60 | 72 |
| 36 | 95 | 72 |

All operators have expressed their belief that they could drill to greater depths without any trouble.

## Size of Coal

The size of coal is dependent on characteristic of the seam, type of head, speed of rotation and advance.

The slack head produces a product denoted as 1½-in. slack, with a small percentage up to 3-in. The sizing is fairly consistent with all size augers. A screen analysis on coal from a 30-in. slack head boring in the Clintwood seam of Virginia showed the following: 1¼ in., 27 pct; ⅜ in. x 1¼ in., 50 pct; —⅜ in., 23 pct.

Lump realization is greatly increased by using the lump head. No accurate screen analysis was available, but one company making a separation on a 2-in. screen stated that they were getting a car of lump for each car of slack. The size of the lump is surprising. It is not at all unusual to see Sewell coal drilled out in lumps as big as 10 to 24 in., see Fig. 4. The smaller sizes are largely a result of the cutting of the kerf around the core and the center hole in the core. For this reason, the use of large diameter augers will greatly decrease the percentage of smaller sizes.

## Quality of Coal Mined

Selective mining of the coal seam can easily be done with coal augers. The high-quality coal of a seam can be mined without any handling of the low-quality bands or partings, thus decreasing production costs and degradation of the product, as shown in Figs. 5 and 6.

Wherever a comparison of analyses has been made between auger-mined coal and conventional or strip-mined coal, a substantial reduction in percentage of ash is noted. An operation in the Blue Gem seam of Kentucky shows an average ash of 2.1 pct for auger-mined coal, compared to 4 pct for conventional-mined coal. Another operation, in the Sewell seam, shows 3.5 pct ash for auger-mined coal and 5.0 pct for broom-swept strip coal.

## Percentage of Recovery

The percentage of recovery is dependent upon the application of the proper size auger to the seam, pillar size, and ability of the operator to drill the hole as deep and as straight as possible. In most operations recovering the pillar between the strip pits and old underground workings, the coal is considered as "bonus" coal and, consequently, the percentage of recovery has not been exceptional.

The highest possible percentage of recovery by drilling the full seam height, leaving no pillar and without overlapping of the holes, is 78.5 pct, see Fig. 7.

Since it has been recommended that the auger diameter be at least 6 in. smaller than the seam or

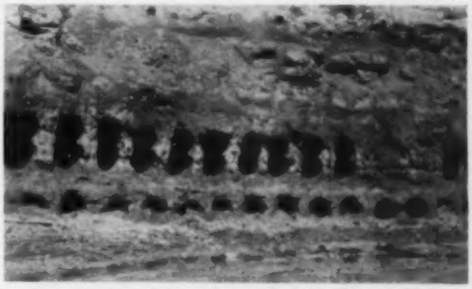

Fig. 5—Selective mining of the upper and lower Thacker seam with 30-in. auger at Thacker, W. Va. Upper seam, 7 ft; lower seam, 4 ft; separated by 2-ft "middle man."

Fig. 6—Auger mounted on old concrete paver tracks for selectively mining the upper and lower Thacker seams, Thacker, W. Va.

band to be drilled, and because it will be necessary to leave some of the coal in for pillar support, the percentage of recovery necessarily will be below the maximum theoretical value.

The following is a comparison of percentage of recovery for various size augers and seam heights allowing a 6-in. pillar between holes.

| Seam Height, In. | Auger Size, In. | Pillar Size, In. | Recovery, Pct |
|---|---|---|---|
| 54 | 48 | 6 | 62.1 |
| 48 | 42 | 6 | 60.1 |
| 42 | 36 | 6 | 57.7 |
| 36 | 30 | 6 | 54.6 |
| 30 | 24 | 6 | 50.2 |

It is obvious from the above values that large augers in thick seams provide the greater percentage of recovery. This is because the pillar size and the allowance for vertical control of the drill is smaller in proportion to the total drilled-out area.

Very little information is available as to the proper size pillar required between holes. Most operators allow for a 6-in. pillar, mainly to decrease the chance of boring into the adjacent hole.

For a 36-in. auger, this leaves only 13 pct of the coal, measured at the smallest cross section of the pillar, to support the roof. This is a small proportion of pillar compared to the amount left in conventional room-and-pillar mining. However, the pillars offer more effective support per unit of area for several reasons: 1—the openings between pillars are comparatively small; 2—beam action is reduced because of the arching effect of the circular cut; 3—there are no shatter cracks from explosives to decrease the effective area of the pillar. For these reasons auger mining is applicable to the mining of seams with very bad roof conditions.

Table I. Average Daily Output of Various Size Augers and Labor Cost at the Machine

| Mine No. | Auger Size, In. | No. of Men | Tons Per Shift | Tons Per Man Shift | Labor Cost Per Ton at the Machine,* $ |
|---|---|---|---|---|---|
| 1 | 16 | 3 | 47 | 16 | 1.02 |
| 2 | 24 | 2 | 60 | 30 | 0.53 |
| 6 | 30 | 3 | 75 | 25 | 0.64 |
| 7 | 30 | 3 | 85 | 28 | 0.56 |
| 8 | 30 | 3 | 75 | 25 | 0.64 |
| 9 | 30 | 3 | 90 | 30 | 0.53 |
| 10 | 30 | 3 | 100 | 33 | 0.48 |
| 11 | 24 | 3 | 55 | 18 | 0.87 |
| 11 | 36 | 3 | 120 | 40 | 0.40 |
| 12 | 36 | 3 | 120 | 40 | 0.40 |

* At $2 per hr.

Proper pillar size will have to be determined by experiment. There have been instances of pillar failure at some of the operations, see Fig. 8, especially on long narrow necks of "strip islands" that have been completely undermined with augers. One company having a near mishap from pillar failure and subsequent sliding of the highwall now places a small wooden prop in the mouth of one of the holes at spaced intervals to give warning in case of roof movement.

## Production and Costs

A few of the companies have an additional labor cost of one or two truck drivers but many of the companies contract for haulage by the ton-mile. Supervision cost is not included.

Table I shows that additional men are not needed for operation of the larger size augers, thereby increasing tons per man shift and lowering labor cost per ton.

Gasoline consumption is slightly higher for the

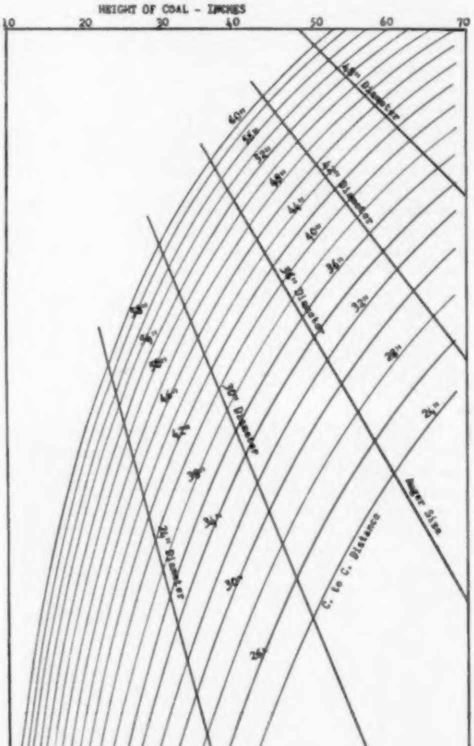


Fig. 7—Percentage of recovery for various seam heights, auger diameters, and center to center spacings.

To Use: Select coal height at top, drop vertically to auger diameter, cross horizontally to center to center spacing, then vertically to height of coal, 42 in.; auger diameter, 36 in.; center to center spacing, 42 in.; recovery, 57.7 pct.

Fig. 8—Pillar failure, Eagle Seam, W. Va. Note pillar coal that has half filled 36-in. hole.

Fig. 9—Mining of pillars between holes.

larger size augers but the increased consumption is not in proportion to the increase in auger size. Twenty gallons per shift for auger and conveyor would be sufficient for any of the above operations. At a cost of $0.25 per gal, this would entail a power cost of $0.05 to $0.10 per ton. Bit cost is negligible. Most of the operators agreed that bit cost was less than $0.01 per ton.

Information is not available on depreciation and maintenance costs. It has been suggested that depreciation be figured at $0.20 per ton by basing a 50,000-ton production life on a $10,000.00 capital investment. Maintenance and repair cost has been tentatively set at the same rate. Insurance cost adds another $0.03 per ton.

A tabulation of cost per ton, excluding transportation, royalty, bulldozer, supervision, etc., shows the following: Depreciation, $0.20; repair and maintenance, $0.20; fuel for auger and conveyor, $0.10; bit cost, $0.01; labor, $0.70; insurance, $0.03; total per ton, $1.24.

These figures substantiate the fact that some operators are mining coal on a contract basis for less than $3 per ton.

## Machine Operation Underground

Underground models of the coal auger have been manufactured and are being used or are awaiting developments of sections for use.

One company in particular, operating in the Cedar Grove seam of West Virginia, is now in the process of developing areas for their underground auger. The seam varies from 48 in. to 52 in. and consists of a 6-in. band of bottom coal, a 4 to 6-in. band of slate, and 38 to 40 in. of clean top coal, of which 30 in. analyzes 2½ pct ash. Roof conditions are bad. The top coal will be auger-mined with a 30-in. auger using a lump type head. The auger sections are 4 ft in length, allowing operation from a 14-ft entry.

The unit is powered with a 33-hp permissible electric motor. The machine has been used on highwalls to drill holes to a depth of 60 ft. It is anticipated that 75-ft holes and possibly 100-ft holes can be drilled without overheating of the motor.

Chain conveyors will be used for transporting the coal from the auger. Entries will be driven full seam height by conventional methods. This permits the conveyor to clear the auger very easily.

The machine crew will consist of three men—an operator to operate the machine, and two operator's helpers, who will attach auger sections, grease, pan-up, and help move. It is expected that the three men will average 100 tons per shift.

## Other Applications

At an operation in Kentucky, a thin seam of coal, 25 to 28 in. thick, which has not been stripped previously, is being auger-mined from the outside. A bulldozer is used to remove enough of the outcrop coal to provide a berm wide enough for the operation of the auger. Sixteen-inch holes are being bored for a distance of 100 ft.

One operator who has two augers working on a highwall in West Virginia is contemplating the installation of an underground machine in the Pittsburgh seam to selectively mine the pillars. The seam at this mine has a bottom band of sulphur balls and a top band of low quality coal.

One manufacturer expressed the hope that the machines would prove adaptable to the mining of the steeply pitching anthracite seams. One machine is already mining coal in a steeply pitching and folded seam in Idaho.

## Conclusion

Auger mining has been proved an easy and cheap method of mining high quality coal from seams of varying quality and conditions. At abandoned strip pits, coal has been auger-mined which might never have been recovered by any other method.

Auger mining holds tremendous possibilities for underground operations. There seems to be reason to believe that the cost per ton of highwall-mined coal could be duplicated underground. Entries could be driven by boring four to six holes close together and removing the thin pillars between holes, as shown in Fig. 9.

Auger mining works equally well in all types of roof conditions. Only the entries need to be timbered. Partings or impure bands in the seam can be left in place.

Four or five machines could be bought for the price of a continuous mining machine or equipment needed to outfit a working section, providing flexibility of operation and eliminating sharp cuts in daily production should a unit break down. The units are simple in design and construction and easily maintained and repaired. The power demand per unit is not high. Existing substation capacity and transmission lines would not be overtaxed. Either slack or lump coal can be mined at a steady flow that makes it possible to use existing face haulage, such as chain conveyors.

# Simultaneous vs Consecutive Working of Coal Beds

by H. H. Hasler

THE mining and removal of coal from two or more beds, either simultaneously or consecutively, in vertically adjacent areas have always been matters of concern to mine operators from both operating and recovery points of view. However, with the progressive introduction and use of electrical and mechanical facilities, such problems assume even greater proportions.

In this paper typical cases occuring in Cambia County, Pa., are given and procedures whereby such problems may be greatly reduced, if not entirely eliminated, are suggested.

Throughout a considerable portion of the Central Pennsylvania bituminous coal region, particularly in Cambria County (Fig. 1), the portion of the region to which references in this paper are made, large areas are encountered where two or more beds of coal occur and have been mined extensively since the earliest days of mining in the county.

Generally, operations were commenced in one bed of coal on a property, following which, as conditions appeared to warrant, operations were commenced in another bed or beds on the same property, in some instances by the same operator.

Operating results by no means have been uniformly successful, as the following review of some typical cases indicates, partly because of lack of experience in earlier cases and in certain later cases to disregard for the experiences of earlier operators. It is suggested that repetitions of such failures may be reduced largely, if not eliminated entirely, by adherence to a few basic principles founded upon past experiences.

### Geology and Stratigraphy

The geology, stratigraphy, and relief of almost all of Cambria County have been studied and reported at length by the U. S. Geological Survey in its Johnstown, Ebensburg and Barnesboro-Patton Folios and other publications, by the Pennsylvania Geological Survey and by various individuals.

All exposed rocks occurring within the boundaries of the county are of sedimentary origin, consisting of alternate beds of sandstone, slate, shale, fireclay, coal, limestone, etc., and all have been classified by the U. S. Geological Survey as extending from the upper strata of the Catskill formation, Devonian system, to and including, in a few hilltop areas, the lower strata of the Monongahela formation, Carboniferous system.

Included within that range is the Allegheny formation, Pennsylvania series, which embraces all of the commercially important beds of coal that occur in the county, viz., the *A*, or Brookville, to the *E*, or Upper Freeport, both inclusive, shown in Fig. 2.

The measures are traversed by a series of anticlines and synclines, extending in a northeasterly and southwesterly direction, which form broad, gently sloping basins (flat to 15 pct pitch, exceptionally to 25 pct). However, the topography of the surface is such that long lines of outcrops of all beds of coal overlying bed *B*, and to a limited extent bed *B* also, occur over large areas, a factor which contributed to the early and extensive development of mining activities in the county.

Earliest mining developments of commercial importance were made in *B*, *C'*, *D*, and *E* beds of coal, and it is in these beds that the principal mining operations are being conducted. To a limited extent, mining operations also have been conducted in local areas in the *A*, *B* rider and *C* beds.

Coal beds being mined today range in thickness from approximately 28 to 60 in. Intervals between the respective beds of coal are variable but conform somewhat to the following general averages: *A* to *B*, 60 to 100 ft.; *B* to *C*, 50 ft.; *C* to *C'*, 70 ft.; *C'* to *D*, 45 ft.; and *D* to *E*, 45 ft.

The following are typical mining cases observed over a period of years in various parts of the county.

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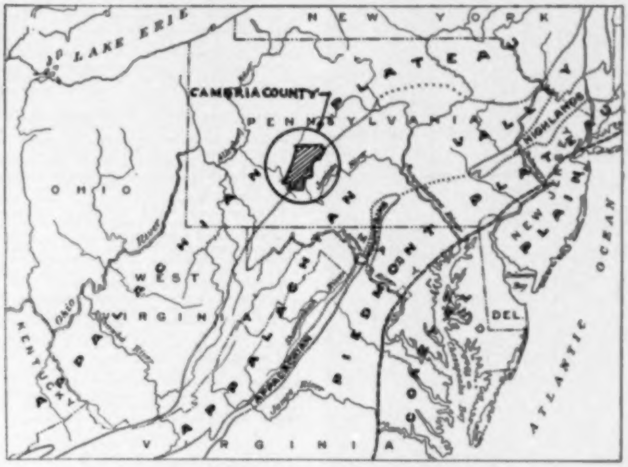


Fig. 1—Central Pennsylvania bituminous coal region.

## CASE NO. 1.

1. **Bed *B*, average 48 in.**
2. **Bed *B*-rider, average 40 in.**
3. **Interval between beds, approximately 18 ft.**
4. **Cover over bed *B*-rider, approximately 100 ft.**
5. **System of mining, room and pillar.**
6. **General observations:**

**(a) The mines were operated** by different operators and no coordination existed between plans of mining or operations in the two mines.

**(b) Bed *B* was developed** about 15 years before bed *B*-rider. Robbing of pillars in bed *B*-rider caused roof breakage and crushing of the pillars along the main haulageway in bed *B* and threatened to close the latter mine. Robbing of pillars in bed *B*-rider workings immediately above critical areas in bed *B* workings was discontinued.

## CASE NO. 2.

1. **Bed *B*, average 40 in.**
2. **Bed *D*, average 42 in.**
3. **Interval between beds, approximately 170 ft.**
4. **Cover over bed *D*, approximately 300 ft.**
5. **System of mining, room and pillar.**
6. **General observations:**

**(a) The mines were operated** by different operators and no coordination existed between plans of mining or operations in the two mines.

**(b) Bed *D* was first** developed throughout approximately 600 acres, the greater portion of the property. Bed *B* was opened and developed about 15 years later.

Removal of pillars in bed *B* mine caused crushing and squeezing of large entry pillars in bed *D* and ultimate abandonment of a considerable portion of the latter property.

## CASE NO. 3.

1. **Bed *B*, average 38 in.**
2. **Bed *D*, average 45 in.**
3. **Interval between beds, approximately 100 ft.**
4. **Cover over bed *D*, approximately 400 ft.**
5. **System of mining, room and pillar.**
6. **General observations:**

**(a) Different operators control** the mines and there is no coordination between plans of mining or operations in the two mines.

**(b) Robbing of pillars** in bed *B* resulted in marked, but as yet not fully determinable, damage to the immediately overlying active workings in bed *D*. Principal damage resulted to strata overlying bed *D*, causing caves and breaking of timbers. In certain areas the timbers were replaced as often as four times. Lateral movements of coal and overlying strata were also clearly discernible in bed *D* areas, which had been rock-dusted just prior to the disturbances.

## CASE NO. 4.

1. **Bed *B*, average 44 in.**
2. **Bed *D*, average 42 in.**
3. **Interval between beds, approximately 145 ft.**
4. **Cover over bed *D*, approximately 300 to 400 ft.**
5. **System of mining, room and pillar in bed *B*; room and pillar and V-system in bed *D*.**
6. **General observations:**

**(a) The mines are operated** by the same operator but no coordination exists between plans of mining or operations in the two mines.

**(b) With few exceptions**, the mining in bed *B* preceded by many years the mining in bed *D* and, except for a few minor breaks which were observed at the bottom of bed *D*, no appreciable effect of such prior mining in bed *B* was observed.

**(c) More recently, however**, a case was noted where pillars were being extracted in bed *B* mine directly under active workings in bed *D* mine. Caving developed simultaneously in a robbed area in bed *B* mine and in the immediately overlying workings in bed *D* mine and required temporary suspension of operations in the affected portion of the latter mine. Robbing of pillars in bed *B* mine in areas directly under critical areas in bed *D* mine was immediately discontinued.

## CASE NO. 5.

1. **Bed *B*, average 28 in.**
2. **Bed *E*, average 46 in. (plus 10 in. bony on top).**
3. **Interval between beds, approximately 220 ft.**
4. **Cover over bed *E*, approximately 300 ft.**
5. **System of mining, room and pillar.**
6. **General observations:**

**(a) The mines were operated** by the same operator but no coordination existed between plans of mining or operations in the two mines.

**(b) Mining in bed *B*** was conducted approximately 20 to 30 years after mining in bed *E*. No effects of mining in either bed were found in the other.

## CASE NO. 6.

**(Reported to but not confirmed by the writer)**

1. **Bed *B*, average 42 in.**
2. **Bed *E*, average 42 in. (plus 8 in. bony on top).**
3. **Interval between beds, approximately 180 ft.**
4. **Cover over bed *E*, 600 to 850 ft.**
5. **System of mining, room and pillar.**
6. **General observations:**

**(a) Main entry pillars** are columnized and mining operations in the two beds of coal are coordinated.

**(b) Plan of operations** provides for mining bed *B* first, allowing two years for subsistence, and then mining bed *E*. This was first tried with a six-months to one-year interval for subsistence, but when trouble was encountered in bed *E*, the two-year period was decided upon.

**(c) When this order** of mining is followed, bed *E* is not appreciably affected except for marked reduction in the amount of water encountered in the mining of that bed, indicating the presence of fractures through which the water percolates to lower strata. Recovery of coal is normal from both beds.

**(d) Marked disturbances** occurred in bed *E* workings where immediately underlying bed *B* pillars had been extracted.

## CASE NO. 7.

1. **Bed *D*, average 48 in.**
2. **Bed *E*, average 40 in.**
3. **Interval between beds, approximately 43 ft.**
4. **Cover over bed *E*, approximately 200 to 300 ft.**
5. **System of mining, room and pillar.**
6. **General observations:**

**(a) The mines were operated** by different operators and there was no coordination between plans of mining or operations.

**(b) The property here** represented was rather small, comprising approximately 300 acres, and the *D* bed of coal was developed over the greater portion of the property about 11 years before operations were begun in bed *E*.

Shortly thereafter, the operator of bed *E* mine claimed that mining out of the bed *D* coal was causing damage to his operations and secured a permanent injunction against the operator of bed *D* mine, which restrained him from causing further damage to bed *E* operations. Consequently, large areas of bed *D* coal were lost.

## CASE NO. 8.

1. **Bed *D*, average 51 in.**
2. **Bed *E*, average 41 in.**
3. **Interval between beds approximately 42 ft.**

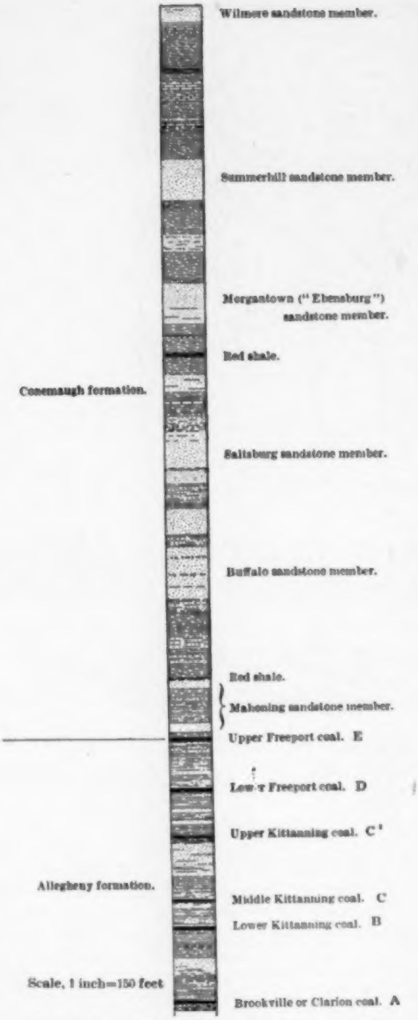


**Fig. 2—Composite diamond-drill and surface section showing the character of the Conemaugh and Allegheny formations in the Johnstown quadrangle.**

U. S. Geological Survey, Johnstown Folio No. 174

4. **Cover over bed *D*, approximately 150 to 200 ft.**
5. **System of mining, room and pillar.**
6. **General observations:**

(a) **Ownership and operation** of the coal and the mines in different parts of the property varied. In certain parts, beds *D* and *E* were owned and operated by the same operator; in other parts, one operator owned and operated bed *E* only, while bed *D* was owned and operated at the same time by another operator.

(b) **To the extent that** beds *D* and *E* were owned and operated by the same operator, the following order of mining was observed:

Bed *D* mine was opened about 12 years before operations began in bed *E*, by which time a considerable portion of Bed *D* property had been mined over but only partially exhausted.

While full retreat operations were being conducted in the more remote sections of bed *D* mine, development work progressed in outlying areas in bed *E* mine.

Main entries in bed *E* mine were projected and driven, with pillars columnized over main entries in bed *D* mine to areas where bed D coal had been completely exhausted. Then they were driven on independent projections.

Pillar extractions in bed *D* mine were unusually clean, resulting in fairly uniform subsidence of the overlying strata, including bed *E*—a factor which contributed materially toward lessening of difficulties incident to subsequent mining of the coal from bed *E*. Timbering and ventilating costs were somewhat higher than they would have been if the underlying bed *D* coal had not been previously exhausted. However, such additional costs were materially offset by a reduction in pumping costs caused by percolation of water from bed *E* workings through the fractured strata, boreholes and shafts to bed *D* workings, from which it was conducted to the surface by way of a drainage tunnel.

(c) **In that portion** of the property where operations in beds *D* and *E* were conducted simultaneously by different operators with no attempt at planning and coordination, intolerable conditions were created in both mines.

Caving of robbed-out areas in bed *D* mine under active workings in bed *E* mine resulted in subsidences which closed passageways in the latter mine and otherwise rendered unmineable large areas of bed *E* coal.

Likewise, impact and shifting of earth pressures resulting from caving of robbed-out areas in bed *E* mine over active workings in bed *D* mine resulted in fractures, displacement, and squeezing of bed *D* coal and adjacent strata to such extent as to seriously damage workings and to threaten their future usefulness.

Here again litigation ensued, followed by the issuance of court injunctions and counter-injunctions.

Differences were finally compromised after both parties agreed to adoption of plans whereby each would confine its mining activities to areas previously agreed upon wherein operations could be conducted with a minimum of further detriment to either party.

Fractures and subsidence of the coal and roof strata in various sections of bed *E* mine, resulting from robbing of the underlying pillars in bed *D* mine, are shown in Figs. 3-6. Fractures and subsidence of the floor strata are present but are not visible in the photographs. No photographs were taken of disturbances which occurred in bed *D* mine as a result of robbing pillars in immediately overlying areas in bed *E* mine.

## CASE NO. 9.

1. **Bed *D*, average 42 in.**
2. **Bed *E*, average 40 in.**
3. **Interval between beds, approximately 45 ft.**
4. **Cover over bed *E*, approximately 300 ft.**
5. **System of mining, room and pillar.**
6. **General observations:**

(a) **Originally, the** mines were owned and operated by different operators and no coordination existed between plans of mining or operations in the two mines.

(b) **Bed *D* mine** was opened and most of the property was worked over before development of bed *E* coal in that area was commenced.

As bed *E* mine was being developed, pillars were being robbed in bed *D* mine directly under such development work, resulting in an intolerable situation.

The operator of bed *E* mine purchased the underlying bed *D* mine and planned not to rob any more pillars in the latter mine until after the immediately overlying pillars in bed *E* mine were robbed.

The effect of robbing pillars and the resultant caves in bed *E* mine was the creation of such pressure and crushing action on bed *D* pillars and adjacent strata so that large areas had to be abandoned and the coal permanently lost.

## CASE NO. 10.

1. **Bed *B* mine, average 30 in.**
2. **Bed *C'*, average 50 in.**
3. **Interval between beds, approximately 110 ft.**
4. **Cover over bed *C'*, approximately 200 ft.**
5. **System of mining, room and pillar.**
6. **General observations:**

(a) **Bed *C'* was developed** and mined to the limits of permissible exhaustion many years before mining operations were undertaken in bed *B*. Both mines were self-draining.

(b) **No effects whatever** of the prior mining of the coal from bed *C'* were apparent in the workings in bed *B* mine.

These ten typical cases, which were selected to exemplify some of the major problems of economics and recovery involved in mining two or more beds of coal simultaneously or one after the other, may be divided into the following three categories.

**Category A.** Cases in which the upper of two or more beds of coal in vertically-adjacent areas was mined to or near the limit of permissible exhaustion before mining operations were commenced in an underlying bed within that area.

Observed cases falling within this category showed no evidence of prior exhaustion of the coal from an upper bed and therefore presented no special problems of economics and recovery, except that in cases where the interval between the beds of coal worked ranged from approximately 40 to 50 ft, e.g., *C'* to *D* and *D* to *E*, regions of high pressure were frequently encountered in the workings underlying those in which large and extensive areas of pillars had been left standing.

All observed workings were self-draining but if they had not been, special precautions would have

been required to guard against sudden and dangerous inrushes of water from overlying flooded areas. Flooding is a principal, though by no means deterring, adverse factor incident to the conduct of mining operations in this order.

**Category B.** Cases in which the lower of two or more beds of coal in vertically adjacent areas was mined to or near the limit of permissible exhaustion before mining operations were commenced in an overlying bed within that area. Among problems of recovery and economics are the following:

1—Unavoidable damage to which the upper bed or beds of coal and adjacent strata were exposed as a result of prior removal of all of the coal from a lower bed without provision for adequate support for the overlying strata. Such injury or damage consists of subsidence, fracture, and parting of the overlying strata and beds of coal within varying ranges.

2—Avoidable damage to an overlying bed or beds of coal and adjacent strata caused by large and extensive pillars of coal left standing in otherwise worked-out areas in an underlying bed.

Injurious effects observed in overlying mine workings were humps in the floor, necessitating extra grading; concentrations of weight of the overlying strata, which caused crushing of the coal and squeezes; also undue fractures in the coal and its adjacent strata, which increased timbering and ventilating costs; and loss of coal beyond normal, unavoidable losses.

However, where pillar extraction in a lower bed of coal had been reasonably complete and ample time allowed for subsidence of the overlying strata, there were large areas in the workings in an upper bed of coal where subsidence of that bed and its adjacent strata was so uniform that there was little evidence of previous mining out of the lower bed. However, lines of successive caves in the lower workings were frequently found as troublesome fracture lines in an upper bed of coal and its adjacent strata.

Escape of gases from the fractured coal and adjacent strata is an ever present hazard which requires constant and close supervision.

Fig. 3—Fractures and subsidence of the coal and roof strata in bed E mine resulting from robbing of the underlying pillars in bed D mine. Interval approximately 45 ft.

Fig. 4—Fractures and subsidence of the coal and roof strata in bed E.

Offsetting, in part, these adverse factors, drainage problems in cases falling within this category generally were found to be simplified because the water generated in the workings in the upper bed of coal percolated through the fractured strata into the lower worked-out areas or was conducted there by means of boreholes or shafts.

**Category C.** Cases in which attempts were made to mine two or more beds of coal simultaneously in vertically adjacent areas.

The record of observed cases within this category, particularly those in which the interval between the beds of coal mined was approximately 165 ft or less, is generally one of failures. These failures ranged from local, though quite costly, displacement and/or crushing of the coal and adjacent strata in the workings in one bed of coal or the other, or both, to cases in which large areas of coal and mine workings were so seriously disturbed that permanent abandonment was required.

Notable among observations made in connection with cases falling within this category are the following:

1—Intervals of as much as approximately 200 ft, e.g., those which prevail between beds *B* and *E*, do not necessarily provide protection for mine workings in the upper bed of coal if the supporting pillars are completely extracted from the workings in the lower bed. (An example of an apparent exception is noted in Case No. 5, possible reasons for which were the thinness of the lower bed of coal, the relatively slow rate of exhaustion (hand-loading under adverse conditions), and the frequent occurrence of "bottom rolls" over which the coal was

frequently not mined. All of these factors resulted in the reduction of the height of caves in otherwise robbed-out areas.)

2—Complete extraction of the pillars from the workings in a lower bed of coal is practically certain to result in serious damage to, or possible destruction of, immediately overlying workings in any bed of coal within a vertical range of at least 165 ft, which is the approximate average interval between beds *B* and *D*.

3—Complete extraction of the pillars from the workings in an upper bed of coal is almost certain to result in serious damage to, or possible destruction of, immediately underlying workings in any bed of coal within a vertical range of at least 45 ft, which is the approximate average interval between beds *C'* and *D* and beds *D* and *E*. It is probable that similar effects would have been produced in cases involving beds of coal separated by somewhat greater intervals, although supporting evidence to that effect is not indicated by these cases, nor is it material in view of the possible destructive effects referred to in Observations Nos. 1 and 2.)

The three foregoing observations refer to effects produced in coexisting "mine workings" in two or more beds of coal within vertically adjacent areas. They do not apply to virgin beds of coal within such areas that might be similarly exposed to the effects of mining in another bed or beds of coal, that being a subject referred to under the headings Categories A and B.

### Suggestions

Experience gained from the cases cited, and many others which have been observed, suggests adherence to the following general principles in cases, as defined, where the mining of two or more beds of coal on the same mining property, either simultaneously or consecutively, is contemplated or in progress.

The simultaneous mining of two or more beds of coal in vertically adjacent areas of a given mining

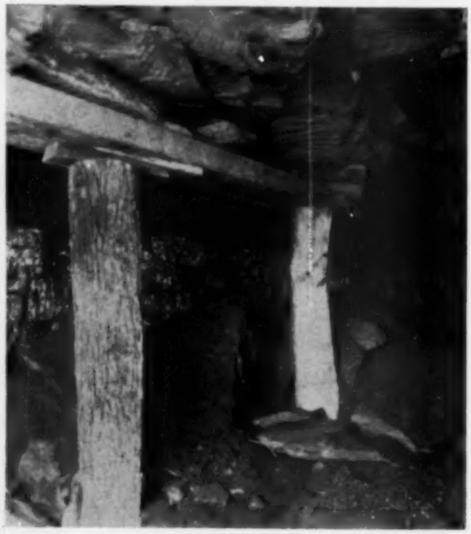

Fig. 5—Fractures and subsidence of the coal and roof strata in bed E.

Fig. 6—Fractures and subsidence of the coal and roof strata in bed E.

property should be avoided generally in cases where the interval between the beds being mined is approximately 160 to 180 ft or less (except necessary development work). In cases where such interval exceeds approximately 160 to 180 ft, a study of local conditions is warranted before simultaneous mining in vertically adjacent areas is undertaken.

In cases where it is found desirable to mine two or more beds of coal simultaneously on the same mining property, but not in vertically adjacent areas, the following general plan of procedure is suggested.

**Subdivide the property** into areas where mining operations (except necessary main entry development in another bed or beds of coal) will be confined to one bed at a time, preferably the uppermost bed first. Continue mining operations in that bed and area to the limit of permissible exhaustion. After subsidence has been completed sufficiently, other workable beds within that area may be mined in sequence while operations in the (preferably) uppermost bed advance into and progress in another area.

The cycle of simultaneous operations thus started may be continued until all workable beds of coal on the property have been exhausted.

**Columnize all main** entry pillars in each bed of coal worked.

**When necessary**, provide barrier pillars along such entries in excess of pillars normally required in cases where only one bed of coal is to be mined.

**Allow for the effects** of draw in the planning and execution of all work.

**Require clean extraction** of the pillars, which will result in more nearly uniform subsidence of the overlying strata of coal and rock and distribution of earth pressures, as an aid to subsequent recovery of the coal from closely overlying and/or underlying (approximately 50 ft or less) workable beds.

**Plan, coordinate** and execute all work carefully that interference of mining operations one with the other will be minimized.

# Fullers Earth, A General Review

by R. C. Amero

FULLERS earth is a general name applied to claylike minerals that have high natural adsorptive powers. They are usually distinguished from ordinary clays by a higher content of combined moisture and a lower apparent density. The definition is based on the ancient use of the material for fulling, or cleansing woolen cloth of oil and grease; a more modern definition should mention the ability to decolorize oil and should differentiate between fullers earth, which is naturally active, and certain bentonites which only develop decolorizing power after being leached with strong mineral acids. The distinction between fullers earth and activable bentonite is not a sharp one, since all types of intermediate clays can be found that are more or less naturally active, yet more or less responsive to acid treatment. The differences seem to depend somewhat on the amount of leaching that has been effected by natural ground waters.

## Physical Properties

The principal mineral constituent of activable bentonite is montmorillonite, a hydrous aluminum silicate to which the following formula is generally assigned:

$$Al_2\,Si_4\,O_{10}\,(OH)_2 \cdot 12H_2O$$

Fullers earth, as well as bentonite, is usually composed of some variety of montmorillonite, but in the United States the largest tonnage of fullers earth is mined from deposits of attapulgite. Attapulgite is a clay mineral composed of monoclinic crystals of colloidal size, having a fibrous shape similar to that of asbestos. A sectional model of the attapulgite "molecule" is shown in Fig. 1. A single unit is about 18.0 A wide and 12.9 A high. The length of the molecule is variable, but this same molecular pattern is repeated to form needlework crystals, rather than flakes, as is characteristic of the montmorillonite crystals. Attapulgite has been assigned the following formula,[1] although actually, the magnesia has been largely replaced by alumina:

$$(OH_2) \cdot (OH)_2 \cdot Mg_5 \cdot Si_8 \cdot O_{20} \cdot 4H_2O.$$

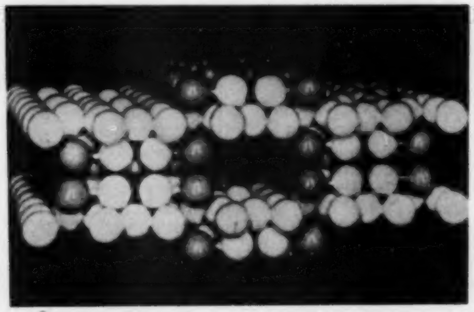

Fig. 1—Model of attapulgite structure.

The fibrous nature of the mineral is clearly shown in the electron micrograph, Fig. 2. Although the deposits contain 5 to 30 pct quartz and carbonate minerals, impurities in the commercial products are held at a low level, principally by selective mining on the basis of oil decolorizing efficiency.

The particle size distribution of this fullers earth has been estimated from settling rates, using sodium citrate as a dispersing agent.[1] Since Stokes' law only applies to spherical particles, the equivalent particle diameter calculated below is probably more nearly an index of diameter rather than length of the needlelike crystals:

| Equivalent Particle Diameter | Distribution, Pct | Arbitrary Size Classification |
|---|---|---|
| 0.05 mm | 0.80 | 0.80 pct sand |
| 0.05-0.02 mm | 10.96 | |
| 0.02-0.01 mm | 9.65 | 42.10 pct silt |
| 0.01-0.005 mm | 11.40 | |
| 0.005-0.002 mm | 10.09 | |
| 2-0.5 micron | 10.67 | |
| 0.5-0.2 micron | 29.09 | 56.58 pct clay |
| 0.2-0.05 micron | 14.86 | |
| 0.05 micron | 1.96 | |

The differential thermal analysis shown in Fig. 3 is unique and supports the theory that this is a distinct mineral species.[2,3] Other general properties of the mineral as shown in Table I.

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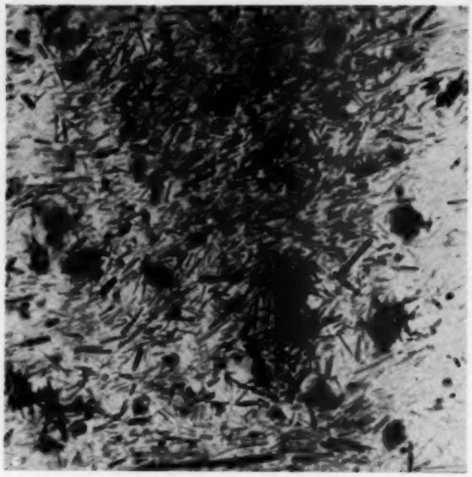

Fig. 2—Micrograph of attapulgite.

To control the properties of fullers earth as an article of commerce, producers depend on three major processing treatments; extrusion, drying, and milling. In the extrusion process, the wet plastic clay is extruded in the shape of rods about ¾ in. diam before drying and milling. The crushed crude clay is kneaded with water in a pug mill, then fed through an auger-type extruder, similar to those employed to form bricks, except designed to operate at higher pressures. By this treatment, laminations in the clay are disrupted and the particles are twisted into a more random orientation. This lowers the apparent density 3 to 4 pct and increases the porosity and the oil decolorizing capacity by about 10 to 25 pct.[4]

The importance of controlled drying is shown in Fig. 4. For a colloidal product that will disperse readily in water, it is necessary to keep drying temperatures below 250°F. To develop maximum adsorptive capacity for moisture vapor, a drying temperature of 600°F seems best, whereas for oil decolorization by the percolation process, an activation temperature of 1000° to 1200°F is necessary.

**Table I. General Physical Properties Florida-Georgia Fullers Earth[1]**

Refractive Index: Alpha—1.506 to 1.522
Gamma—1.530 to 1.540
Birefringence: 0.021 to 0.032
Optical Character: Negative
Hardness: Approx. 2.0
Base Exchange Capacity: 25-30 milliequivalents per 100 g
pH: 7.9 to 8.2 in distilled water
Specific Gravity: 2.2 to 2.4

| Typical Chemical Analysis, Pct: | |
|---|---|
| $SiO_2$ (as silicates) | 2.36 |
| $SiO_2$ (as silica) | 10.11 |
| $SiO_2$ (hydrated) | 2.42 |
| $SiO_2$ (combined with bases) | 42.63 |
| $Al_2O_3$ | 15.43 |
| $Fe_2O_3$ | 4.95 |
| FeO | 0.30 |
| CaO | 1.75 |
| MgO | 2.44 |
| $Na_2O$ | 0.27 |
| $K_2O$ | 0.66 |
| $CO_2$ | 0.84 |
| Loss below 105°C[a] | 6.39 |
| Loss above 105°C[a] | 9.45 |
| | 100.00 |

[a] Moisture content depends on the degree of calcination; this analysis is based on an average commercial product.

Absorbent grades used as floorsweeping compound will "mud up" in water unless heated above 700°F.

For many years, fullers earth was processed primarily for oil decolorization, and the hydrous colloidal form was practically unknown. As a plastic clay or an electronegative colloid, it compares favorably with the swelling bentonites. Bentonite suspensions are more thixotropic and more effective for sealing off a porous surface, but the fullers earth suspensions are more viscous and more resistant to the coagulating effect of electrolytes. Colloidal fullers earth can be expected to have many industrial uses as its properties become more widely known.

Milling reduces the fullers earth to granules or powders in a series of crushing, grinding and sifting operations. Coarse sizes and closely graded fractions offer less resistance to fluid flow. Smaller sizes are less costly and usually have higher adsorptive capacity since they afford more intimate contact between the fullers earth and the fluid being treated. Grades from 2/4 to 16/30-mesh are used if gases or vapors are to be passed through a bed of fullers earth. Sizes from 8/16 to 80/100-mesh are preferred if liquids are to be treated in the same manner. Powdered grades, ranging down to 95 pct finer than 325-mesh, are used if the earth is to be slurried in a liquid.

Floorsweeping compounds are of wide mesh range for economy, although particles finer than 60-mesh are avoided, since they either cause caking or dustiness. As a filler material for intimate blending, as in an insecticide mixture or plastic molding compound, finely powdered grades are used.

## Fullers Earth Deposits

Since all clays are colloidal and most of them will decolorize oils to some extent, it is not surprising that deposits classified as fullers earth are found in many parts of the world. Japan and Great Britain are among the most important foreign producers, but the production and consumption in the United States exceeds that of any other nation. At least 18 states have reported production at some time in the past 60 years; the more important deposits are shown in Fig. 5. All of these are reported to be sedimentary in nature except those of Arkansas, which occur in basaltic dykes. The relative production of the various states in recent years is shown in Table II.

Half of the domestic production in recent years has originated in the Georgia-Florida area, principally from a deposit that forms a practically continuous bed under Gadsden County, Fla., and extends into several adjoining counties in both states. Except where badly eroded, it consists of two layers about 4 ft thick, separated by 2 ft or less of harder, more brittle clay, locally called sandrock. The fullers earth is practically level, and overburden varies with the contours of the land. Economical mining is usually limited to 30 to 50 ft of overburden, although up to 75 ft of overburden has been removed on some occasions. Related deposits of poorer quality extend as far south as Manatee County in Fla., but the deposits farther north in Georgia more nearly resemble the Porters Creek clay of the midwest, which is not an attapulgite.

The attapulgite, or "floridin" deposit is classified as part of the Alum Bluff group in the Hawthorn formation, overlying the Chattahoochee limestone. This deposit, indicated by shaded area in Fig. 5, has never been specifically outlined, but the outcrop-

pings and former commercial operations in Leon, Jefferson, Alachua, Marion, Manatee, and other counties indicate the general shape of the deposit. Although some authorities consider all bleaching clays to have been formed by the leaching of volcanic ash, no volcanic detritus has ever been found in this deposit, and it is probably an erosion product from crystalline rocks of the Piedmont plateau in northwestern Georgia. It is assumed that particles of submicroscopic size were transported by water and deposited on the old Florida peninsula when the sediments of the coastal plain were being accumulated. Continental and marine deposits occur both above and below the fullers earth, indicating that the beds were formed during a transitional period, probably in shallow fresh water along the seacoast.

About 35 pct of domestic fullers earth comes from Texas, and most of this occurs in a deposit that runs practically parallel to the Gulf Coast line, and extends from Grimes County, southeast of San Antonio, through Gonzales to Walker County and beyond. A smaller amount of fullers earth is found in the Taylor marl and Navarro limestone, which are also roughly parallel to the Gulf coast, but are farther inland. The useful portions of these deposits vary from 6 to 20 ft in thickness. Although the Texas fullers earth contains adequate evidence of volcanic origin and montmorillonite structure, it seems to be associated with an ancient coast line,

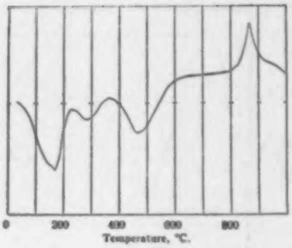


**Fig. 3 — Differential thermal analysis of attapulgite.**

**Table II. Relative Production of States***

| Year | Alabama | California | Florida and Georgia | Nevada | Texas | Illinois | Other States | Total |
|---|---|---|---|---|---|---|---|---|
| 1932 | | | | | | | | |
| Short Tons | 32 | 100 | 144,922 | —— | 36,381 | —— | 46,874 | 228,309 |
| Value, $ | 288 | 2250 | 1,462,794 | —— | 365,374 | —— | 397,021 | 2,227,727 |
| 1933 | | | | | | | | |
| Short Tons | 266 | —— | 153,703 | 5,974 | 31,893 | —— | 32,316 | 224,152 |
| Value, $ | 2028 | —— | 1,426,979 | 61,571 | 308,096 | —— | 281,966 | 2,080,640 |
| 1934 | | | | | | | | |
| Short Tons | —— | —— | 148,319 | —— | 32,763 | —— | 39,182 | 220,264 |
| Value, $ | —— | —— | 1,407,380 | —— | 325,397 | —— | 352,304 | 2,085,081 |
| 1935 | | | | | | | | |
| Short Tons | —— | —— | 145,236 | —— | 40,925 | —— | 41,584 | 227,745 |
| Value, $ | —— | —— | 1,491,764 | —— | 391,641 | —— | 346,824 | 2,230,229 |
| 1936 | | | | | | | | |
| Short Tons | —— | —— | 139,376 | —— | 46,855 | —— | 44,583 | 230,814 |
| Value, $ | —— | —— | 1,426,346 | —— | 462,656 | —— | 375,976 | 2,264,978 |
| 1937 | | | | | | | | |
| Short Tons | —— | —— | 131,100 | 4,485 | 49,530 | —— | 41,080 | 226,165 |
| Value, $ | —— | —— | 1,441,588 | 51,718 | 473,408 | —— | 329,380 | 2,296,094 |
| 1938 | | | | | | | | |
| Short Tons | —— | —— | 91,031 | 5,984 | 37,998 | —— | 35,839 | 170,852 |
| Value, $ | —— | —— | 987,391 | 57,490 | 358,980 | —— | 303,999 | 1,707,869 |
| 1939 | | | | | | | | |
| Short Tons | —— | —— | 91,947 | —— | 38,338 | —— | 36,785 | 167,070 |
| Value, $ | —— | —— | 1,035,666 | —— | 359,058 | —— | 297,731 | 1,691,855 |
| 1940 | | | | | | | | |
| Short Tons | —— | —— | 79,898 | —— | 34,039 | —— | 32,631 | 146,568 |
| Value, $ | —— | —— | 917,365 | —— | 277,229 | —— | 276,489 | 1,471,083 |
| 1941 | | | | | | | | |
| Short Tons | —— | —— | 91,925 | —— | 77,033 | 26,676 | 11,812 | 207,446 |
| Value, $ | —— | —— | 1,075,318 | —— | 713,085 | 209,577 | 113,694 | 2,111,674 |
| 1942 | | | | | | | | |
| Short Tons | —— | —— | 83,007 | —— | 85,012 | 30,421 | 5,804 | 204,244 |
| Value, $ | —— | —— | 1,091,062 | —— | 712,303 | 264,611 | 71,694 | 2,139,670 |
| 1943 | | | | | | | | |
| Short Tons | —— | —— | 105,647 | —— | 94,137 | 63,909 | 7,974 | 271,667 |
| Value, $ | —— | —— | 1,444,936 | —— | 728,141 | 578,805 | 118,926 | 2,867,806 |
| 1944 | | | | | | | | |
| Short Tons | —— | —— | 128,654 | —— | 111,212 | 42,277 | 12,594 | 294,737 |
| Value, $ | —— | —— | 1,833,682 | —— | 916,159 | 390,346 | 156,877 | 3,297,064 |
| 1945 | | | | | | | | |
| Short Tons | —— | —— | 134,401 | —— | 103,076 | 43,644 | 15,227 | 296,308 |
| Value, $ | —— | —— | 1,939,035 | —— | 931,878 | 403,084 | 189,916 | 3,463,913 |
| 1946 | | | | | | | | |
| Short Tons | —— | —— | 144,212 | —— | 110,693 | 33,134 | 10,711 | 298,752 |
| Value, $ | —— | —— | 2,100,652 | —— | 1,157,892 | 296,637 | 147,812 | 3,702,993 |
| 1947 | | | | | | | | |
| Short Tons | —— | —— | 168,557 | —— | 102,901 | 37,740 | 19,870 | 329,068 |
| Value, $ | —— | —— | 2,699,660 | —— | 1,199,726 | 388,935 | 372,273 | 4,660,614 |
| 1948 | | | | | | | | |
| Short Tons | —— | —— | 188,014 | —— | 92,310 | 37,942 | 23,815 | 342,081 |
| Value, $ | —— | —— | 3,224,169 | —— | 1,162,336 | 410,678 | 476,068 | 5,273,851 |

* Tabulated from *Minerals Yearbooks*, U. S. Bur. of Mines.

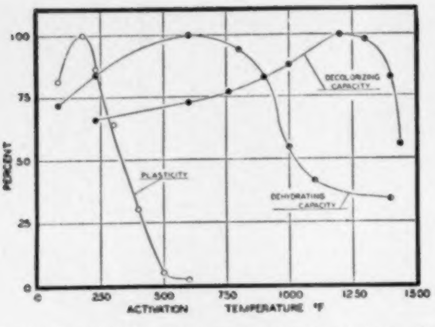


Fig. 4—Effect of drying temperature on properties of fullers earth.

as was the attapulgite described above and the Porters Creek clay described below.

Porters Creek clay runs from Missouri through Illinois, Kentucky, and Tennessee and into Mississippi and Alabama. It is possible that the fullers earth of central and northern Georgia is closely related to this material, although maps of the Porters Creek clay are never extended to include the Georgia deposits. About 10 pct of domestic fullers earth production is mined from the Porters Creek deposit in Pulaski County, Illinois, where it reaches a thickness of 60 ft. Production is also occasionally reported from the other states in which this clay is found. The geological relationship of Porters Creek clay and other domestic fullers earth deposits[3] is as follows:

Cenozoic

- Miocene: Hawthorn Formation, Georgia and Florida, fullers earth.
- Oligocene: Vicksburg Group: Mississippi bentonite; Bentonite clays in Florida, Georgia, Alabama.
- Eocene: Jackson Formation: Georgia bleaching clay, Mississippi bentonite and bentonitic clay; Alabama bentonitic clay (Probably also Texas fullers earth).
- Lisbon Formation: Alabama bentonitic clays (Clarke and Choctaw counties).
- Porters Creek Clay: Southern Illinois, Southeastern Missouri, Western Kentucky and Tennessee, Mississippi and Alabama.

Mesozoic

- Upper Cretaceous:
  - Eutaw Formation: Northeastern Mississippi (Probably also bentonitic fullers earth in Taylor marl and Navarro formation of Texas).

Paleozoic

- Ordovician
  - Chickamauga limestone: Northwestern Georgia, Northern Alabama, Kentucky and elsewhere.

Porters Creek clay and all of the western fullers earths are 50 to 80 pct as efficient as Georgia-Florida clay for decolorizing oil. The exceptions to this rule are limited to certain minor uses, particularly in the refining of vegetable oils. For this reason, the Georgia-Florida material serves the petroleum industry in the entire eastern half of the country, and the lower grade materials are justified principally by lower mining costs and lower freight rates into adjacent refining areas. Fullers earth quality is always established by laboratory scale oil decolorizing tests; no physical or chemical test has been found that will predict or fully explain this decolorizing action.

California and Utah have consistently produced a small amount of fullers earth in recent years, but production from other states has been sporadic, and often for rather specialized purposes. For example, the fullers earth of Massachusetts has been used as a binder for abrasive grinding wheels, and Porters Creek clay from Mississippi was sold exclusively as a floorsweeping compound.

## History of the Industry

The use of fullers earth for "fulling" dates back to the Middle Ages in England, and to Greece and Rome in ancient history. Domestic interest in fullers earth has been traced back to 1880, when N. K. Fairbanks and Co., Chicago, learned that clay was being used in the Orient to improve the color of olive oil. After extensive testing with all of the clays available to them at that time, they settled on English fullers earth as the best decolorizing agent for cottonseed oil.

The first discoveries of fullers earth in the United States were reported in 1891 at Alexander, Ark.,


Fig. 5—Principal deposits of fullers earth.

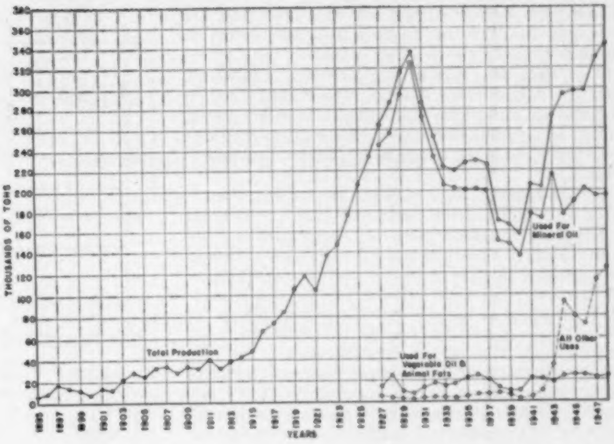


**Fig. 6 — Domestic fullers earth production.**

Tabulated from Minerals Yearbook.

and in 1893 at Quincy, Fla. From an output of 6900 tons in 1895, the production of fullers earth grew with the petroleum industry up to a peak of 335,000 tons in 1930. As shown in Fig. 6, almost 95 pct of this went to petroleum refineries and almost all of the remainder to vegetable oil refineries. Less than 1 pct went to miscellaneous consumers. Whereas oil refining activity stayed at a practically constant level from 1930 to 1935 and then began to expand rapidly, fullers earth consumption dropped steadily to a low of 146,000 tons in 1940. Better regeneration equipment in the refineries lengthened the useful life of the clay; solvent refining and other new techniques reduced the quantity of clay required. Serious competition was being encountered from the more active acid-treated clays and synthetic magnesium silicate, and from the more rugged activated bauxite. A better fullers earth was needed to hold the refinery markets as well as development of new outlets to replace the refining business that was permanently lost. In the interest of self-preservation, some of the larger companies ventured into the production of active bauxite and acid-treated bentonite and started investigations of synthetic adsorbents, particularly magnesium silicates.

The extrusion process mentioned previously was developed about 1936. This was most timely to prevent a widespread changeover to bauxite in the lube oil refineries, since the cost analyses and advantages of each of the two adsorbents were quite evenly matched until extrusion appeared.[6, 7] Fig. 7, which is based on plant records, shows that the less efficient crude fullers earth is more responsive to this treatment than the better crudes. Therefore, it was possible to use many deposits that were formerly too low in quality, and the quality of shipments to oil refineries was not only improved, but also became more uniform. The impact of the extrusion process on the fullers earth industry is demonstrated in Fig. 8, which is a tabulation of the quality of shipments averaged from daily quality control records. The improvement between 1935 and 1937 reflects the adoption of the extrusion process. Bauxite has found a place in the filtration of waxes and certain types of oils, but because of the improvement in fullers earth and the virtual exhaustion of the better deposits of bauxite, it no longer threatens the main uses of fullers earth.

Between 1935 and 1940, new markets were developed for fullers earth as a viscosity-building agent in oil well drilling fluids and as a decolorizing filter aid for used dry cleaning solvents.

From 1940 to 1945, wartime conditions accelerated the demand for all grades in all uses, and at the time when the industry was least prepared to handle it, a remarkable new outlet developed. In 1942, granular fullers earth became popular as a floorsweeping compound for oily, slippery floors. The material did not have to be screened to narrow mesh sizes; quality variations of 10 pct or more could not even be detected by the customer. The demand was enormous. At the same time, but in a less spectacular fashion, a market gradually unfolded for the powdered grades as absorbents and conditioners for the new, complex insecticides such as DDT and BHC. In the Georgia-Florida area, where dust had been accepted as an unsaleable byproduct ever since the refining market had been lost to acid-treated bentonite in 1930, this new outlet was doubly welcome. In the postwar period, the demand for fullers earth has continued to increase with the general business index until tonnages stand once again at the 1930 level.

### Changed Production Methods

In terms of tonnage, the industry may have completed a 20-year cycle, but it is not back where it started. Now only 66 pct of the annual production goes to mineral and vegetable oil refineries, instead of 99 pct. In every aspect of the business, machinery and procedures are more modern and economical.

For prospecting, tractor-mounted, power-driven augers have now come up in efficiency and down in cost to the point where they can replace a prospecting crew with hand augers for taking samples in wooded areas and on soft ground. The newly adopted bulldozer and carryall techniques clear woodland and work strip mines more economically, and at higher overburden ratios than steam shovels, draglines, and dinky trains. A dozen men now mine crude earth at the same rate as 50 or 60 men just

10 years ago. Rotary dryers are still preferred for drying the clay, but the trend is to dryers 6 to 7 ft in diam and 80 to 100 ft long, equipped with automatic controls, in place of the manually controlled dryers 5 to 6 ft in diam and 40 to 60 ft long. Better fuel economy and more uniform products are being obtained as a result, especially where clay temperatures of 800° to 1200°F are required for "calcined" products.

Little change has been made in the milling operation in which the dried lumps of clay are ground and sifted to granular sizes on conventional flour mill machinery, with corrugated rolls and wire and silk screens. Since the granular sizes are most valuable, the art of gradual size reduction and closed-circuit grinding is highly developed, and 65 to 70 pct can be recovered in the 16/30 and 30/60-mesh sizes. Perhaps the major improvement in milling operations in the past 20 years has been the installation of automatic weighing equipment to check screening yields and serve as a guide in adjusting mill rolls. The patented technique of Raymond-milling damp fullers earth before the final drying step also deserves mention.[8] By this method, it is possible to produce powders consisting of rounded particles with a minimum of dust and extreme fines; fullers earth treated in this manner will filter liquids at more than twice the flow rate that can be used on an ordinary fullers earth, with the same pressure drop, although both powders are substantially finer than 300-mesh.

In the shipping department, burlap bags or bulk carloads are used for refinery accounts, but paper bags are preferred for fine mesh products and for shipments to nonrefinery accounts that do not want to be bothered returning empty bags for credit. Shipping departments have been modernized to the extent of using valve bags and some carloading aids, such as portable conveyors, but lift trucks, palletized loads, and airveying systems have not yet been generally adopted.

### Changed Marketing Methods

When 95 pct of the fullers earth went to a few refineries, one or two salesmen could canvass the whole market with no assistance from advertising or distributors. Most shipments were carload quantities direct from producer to consumer, although orders for smaller quantities were tolerated. The production control laboratory would run tests to assist customers with technical problems; the same laboratory devoted occasional spare time to investigating new uses for fullers earth.

The industry still competes for the oil refining business as its primary outlet. Technical service and engineering data are the salesman's chief aids in this competition. For the other markets, there is an increasing use of generalized literature, eye-appealing advertisements, jobber and distributor connections. This is an acknowledgment of the new markets—well drilling mud, insecticide blending, dry cleaning and floorsweeping—where customers are more numerous, more widely scattered and individually consume smaller tonnages. Research programs have been developed to serve the existing applications and develop new ones. In spite of the stable or declining market in petroleum refining, fullers earth has a future as a colloid, adsorbent, filler, filter aid, catalyst, and absorbent.

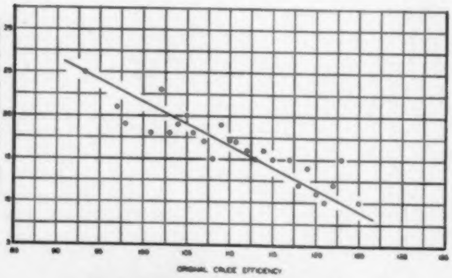

Fig. 7—Clay response to plant extrusion.

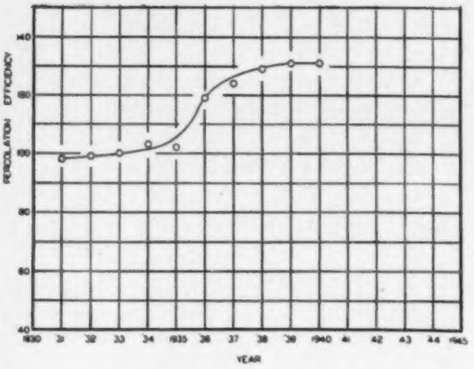

Fig. 8—Average yearly weight efficiency.

### References


[1] O. G. Caldwell and C. E. Marshall: A Study of Some Chemical and Physical Properties of the Clay Minerals Nontronite, Attapulgite and Saponite. Univ. of Missouri Agr. Expt. Sta. (1942).

[2] W. T. Granquist and R. C. Amero: Low Temperature Nitrogen Adsorption Studies on Attapulgite (Floridin). *Journal* Amer. Chem. Soc., **70**, 3265 (1948).

[3] R. E. Grim and R. A. Rowland: Differential Thermal Analyses of Clay Minerals and other Hydrous Materials. *Rept. of Investigations* 85, Illinois State Geol. Survey (1942).

[4] R. C. Amero and R. G. Capell: Effect of High Pressure Extrusion on the Adsorption Capacity of Floridin. *Petroleum Refining* (1943) **22**, No. 1, p. 82.

[5] Clay Investigations in the Southern States. U. S. Geol. Survey *Bull.* 901, (1935).

[6] F. W. K. Hartshorne: Earthy Cellular Decolorizer Suitable for Treating Oils. U. S. Pat. 2,079,854, May 11, 1937.

[7] K. Ikeda, H. Isobe, T. Okazawa, and R. Kenkyûjo: Formation of Earths for Drying Air. Japan, Pat. 42,368, April 20, 1922.

[8] T. C. Atwell: Grinding Process for Filter Aids. U. S. Pat. 2,390,490, Dec. 11, 1945.

[9] R. C. Amero, R. G. Capell, and W. H. Wood: Fullers Earth as a Binder for Catalysts and Adsorbents. *Petroleum Refining* (1946) **25**, pp. 117-119.

[10] C. Wythe Cooke: Geology of Florida. Florida Geol. Survey (1945).

[11] R. P. Humbert: Particle Shape and Behavior of Clays as Revealed by the Electron Microscope. *Bull.* Amer. Cer. Soc. (1942) **21**, No. 11, pp. 260-263.

[12] Twentieth Annual Report, Florida State Geol. Survey (1929).

[13] Robert O. Vernon: Florida Mineral Industry. Florida Geol. Survey, *Bull.* No. 24 (1943).

# INDUSTRIAL SALTS:

## Production at Searles Lake

by J. E. Ryan

TRONA, Calif., is a miniature urban community of some 3500 people, located on the northwest shore of dry Searles Lake in the extreme northwest corner of San Bernardino County, approximately 186 miles north and east of Los Angeles. Since it is situated on the Mojave Desert, a typically desert climate prevails with wide variations in temperature between day and night, extreme daytime summer heat, and cool to cold winters. Rainfall averages somewhat less than 4 in. per year, and dust storms are common. The rate of evaporation, however, is great, amounting to 6 to 9 ft of water per year. The extremely low humidity makes the summer heat of 110°F tolerable with only a mild, temporary discomfort.

### Nature of Deposit

During the periods when Searles Basin was flooded, the waters that passed through Indian Wells Valley spread out to form a broad, shallow lake providing, in effect, a settling basin for suspended sediment. The drainage into the deeper and more isolated Searles Basin thus was clarified to a great degree before concentration began. Today, the elevation of the dry surface of Searles Lake is 1618 ft, and the salt deposit measures 5 x 7 miles.

At the eastern and northeastern margins of the main playa zone and just at the foot of the alluvial slope of sand and coarser wash from the Slate Range mountains, a rim of crusted salts rises a few feet above the level of the flat. The deposit is a saline efflorescence composed of salts that were presumably brought up with rising ground waters to be deposited at the surface by solar evaporation. This deposit consists chiefly of trona, and it is after this Trona Reef that the town Trona was named. Strip mining operations have been conducted in the past at infrequent intervals for the recovery of crude trona salts.

The main focal point of interest in Searles Lake from a commercial standpoint is the main salt body located almost centrally in the basin. The exposed portion of this porous saline deposit covers approximately 12 sq miles and averages 71 ft deep. Its interstitial voids, which constitute 50 pct of the total volume, are permeated with a brine, which is in equilibrium with the soluble salt deposits. The brine is the raw material for the operations of the American Potash and Chemical Corp. plant at Trona, shown in Fig. 1. The soluble salt deposits are of interest for their potential values in future technologic development. The brine, which is stratified according to slight differences in density, stands usually within 6 in. of the surface of this exposed, firm, salt body. The surface is usually dry and will support the weight of heavy mobile units and drilling equipment. Occasionally, however, surface waters from the higher watersheds encroach upon the main salt body during infrequent periods of precipitation on the surrounding mountains. This water dissolves surface salt, becomes a dilute brine, and has been observed to stand as high as 18 in. above the salt surface when undisturbed. Windstorms will shift the water back and forth across the lake surface.

The exposed salt body is surrounded by additional submerged areas of commercial soluble salt deposits covering some 20 sq miles, hidden from view by marginal playa mud. These vary in depth up to as much as 30 ft. Thus, the outline of exposed and submerged salt deposits of commercial value is estimated to cover a total area of 32 sq miles, which is roughly circular but slightly elongated from northwest to southeast. It has been estimated that each square mile contains about 100 million tons[2] of alkali salts.

The results of drill borings in the past 15 years have brought to light the interesting fact that the main salt body lies superimposed on an impervious mud deposit from 10 to 15 ft thick containing relatively little soluble salt. Under this deposit lies a second soluble salt body 35 ft deep. The lower salt body is interspersed with numerous insoluble mud lenses and its composition is considerably different from that of the primary, or main salt deposit. Recent drill borings have not penetrated beyond 300 ft. They have, however, revealed that underlying the lower salt body, the mud sediments carry deposited minerals of trona, nahcolite, mirabilite and much less soluble carbonates or sulphates of calcium and/or magnesium. This structure is shown in Fig. 2.

### Current Lake Survey Program

Several hundred holes have been drilled in the deposit. However, to carry out a thorough and carefully correlated study of the composition of the soluble salts and other minerals in the dry lake basin, a drilling program was inaugurated recently and is now nearing completion. In this survey, pattern drill holes are sunk at regular ½-mile intervals to a depth of approximately 150 ft.

Drilling equipment consists of a No. 51 C. P.

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## Geologic History

Searles Lake occupies a basin lying between the Argus Range on the west or northwest and the Slate Range on the east. The basin was occupied by at least one deep lake, traces of which are evidenced by the records of ancient shore lines and water channels that stand forth on the surrounding ranges.[1] While the waters stood at their highest position, the basin was flooded to a depth of 635 ft above the present dry lake surface, and covered an area of 384 sq miles. The lake historically extended into Salt Wells and Indian Wells Valleys. For several thousand years Searles Lake must have been one of a series, or chain of lakes joined by rivers, which resulted from the overflow of Owens Lake to the northwest. The flood waters passed from Owens Valley, at an elevation of 3760 ft, through Indian Wells Valley into Searles Valley at an elevation of 2260 ft. The waters overflowed Searles Valley into Panamint Valley and finally into Death Valley. The fact that Searles Basin for a time overflowed into Panamint Valley and beyond evidently did not prevent the accumulation and deposition in the Searles Basin of an immense mass of solid crystalline salts and mother liquor brine.

The main salt deposit of Searles Lake represents a crystalline product of desiccating solutions, of which the desiccation has not yet been carried to the final stages. Geological survey indicates that this last period of desiccation, since Owens Lake last ceased to overflow, was somewhat less than 4000 years ago. The residual mother liquor of the Searles deposit still constitutes a large proportion of the mass. It does not lie on the surface of the salts but rather permeates the deposit that has been built up in a loose or open-texture manner. Evaporation at the surface is counterbalanced by percolation or seepage from bordering slopes.

Mitchell Diamond Size "A" drill rig, and a Sullivan Size "A" core drill. Both rigs are equipped with positive screw feed, chucks, and quills for standard drill rods. The rigs are mounted on wide-tired standard wheels for mobility and are designed for surface drilling.

Core barrels ranging in sizes from 2-in. to 15-in. OD may be used as desired. Since large crystals, frequently encountered, may wedge in a 2-in. core barrel, the larger core barrels generally are used. In the present field survey the 9-in. core barrel, shown in Fig. 3, has been made standard equipment. Many types of core barrels have been tested, but the most suitable is the simplest in design. This core barrel is a piece of thin-walled seamless tubing, 4.5 ft long. The cutters consist of tempered steel saw teeth cut in the end of the tubing, with points of 3/16-in. Stoodite, a hard facing alloy, welded to the cutting edges. Circulation for removing cuttings and cooling the bit as used in standard core drilling methods is not required. The bit is cooled by the brine that permeates the salt body.

In the top of the core barrel, a vent, equipped with a plug, is provided through which air may be introduced under pressure to displace core contents. This plug is inserted in the vent after the barrel has been lowered below the brine level, 6 to 8 in. below the exposed salt surface. As drilling progresses, the core enters the barrel, displacing the brine from within. The displaced brine is forced down along the wall of the barrel and out, carrying the cuttings along with it. Cuttings that remain behind pack tightly around the core and serve to hold it in place with no need for a core-catching device since the core barrel is brought to the surface at the end of the drill run. The core is then freed from the barrel by opening the vent and applying pressure if necessary.

Core recovered is logged and sampled for chemical analysis. The core is also subjected to field tests for porosity. Calculations based upon the results of chemical analyses of the cores are also used to determine porosity. Both sets of data are in good agreement.

For cleaning holes following drilling operations, the air-jetting technique is employed. A portable air compressor capable of delivering at 125 psi is employed to bring up about 400 gal per min of brine. In certain areas, it is necessary to cement casing in the hole to depths up to 30 ft to prevent caving of surface material.

After a hole is drilled, the brine is allowed to stand undisturbed for several days. Samples of the brine are then taken at regular depth intervals to determine its quality at respective depths. Fluorescent dye, color tests tend to indicate the existence or absence of brine flows toward low pressure areas, and by systematic sampling and testing at regular intervals, changes in brine composition in affected areas due to pumping are determined.

### Brine-Producing Wells

To drill a brine-producing well, a 10, 15, or 18-in. diam reamer with Stoodite cutting bits is selected. The 18-in. type reamer is shown in Fig. 3. Cuttings are flushed from the hole by a continuous flow of air. By this procedure, a hole may be drilled to a depth of 80 ft within a 16-hr drilling time. The well is cased with 10-in. pipe to within 10 ft of the mud interface underlying the upper salt body, and the annular space between the casing and salt deposit is filled with concrete. This procedure is followed to preclude draw-down of upper strata or surface brines into the well. The well casing, which is made to stand 1 ft above the lake surface, is built up with standard 10-in. flanged pipe to a height 4 ft above the lake surface.

Individual pumps are mounted directly on the top of the flanged 10-in. standard pipe. The pumps are vertical, turbine type, fitted with individual 15 hp motor drive and weatherproof electrical equipment. The shafting and pump bowls extend down about 10 ft. The pump will deliver about 100 gpm against 140 psi of head, or line pressure. Each well is connected through a check valve to the main header, which carries brine into the plant storage tanks. A total of 34 producing wells, spaced at 500-ft intervals, are pumped continuously to supply 17,000 tons daily of raw brine to the main plant evaporative process. The brine is pumped 2 to 3 miles through 8-in., 10-in., and 12-in. branch iron pipe headers, and finally over a distance of 4 miles

Fig. 1—Aerial view of Trona plant from northwest. Recently constructed carbonation plant is in foreground. Abandoned solar evaporating pond is to right of plant effluent on Searles Lake in background.

through buried 14-in. main transite line to the brine storage tanks.

In addition, eight producing deep-wells are pumped continuously to supply approximately 8000 tons per day of lower structure brine to a carbonation process. These wells are spaced at 500-ft intervals and are cased with stainless steel 10-in. tubing to depths of 115 ft below the lake salt surface. The deep-well brine is pumped through concrete-lined 10-in. iron pipe into a buried 12-in. transite header, which leads to the carbonation plant primary towers.

## Commercial Plant

The Trona plant represents an investment of about $32 million, and employs some 1500 workers in the production and marketing of 1800 tons daily of sodium, potassium, and lithium salts, including sodium borates, and also bromine and various bromides. The plant operates two processes that are relatively independent of one another, each of which uses a separate brine from different depths in the lake salt deposits as a source of raw material. Table I shows the composition of upper and lower structure brines as pumped.

The main plant process is a cyclic, closed circuit, in which raw brine from the primary salt deposit is subjected to successive evaporative and cooling steps to effect the segregation of selected salts through fractional crystallization. The carbonation plant process consists of carbonation, utilizing waste flue gas from the power plant boilers as a source of $CO_2$ to precipitate bicarbonate of soda, which is calcined to soda ash with the recovery of $CO_2$ gas. This gas is recycled to the secondary carbonating towers and the soda ash is bleached and further processed for the removal of impurities. The carbonation plant process recently was covered in a paper entitled *"The Utilization of Natural Brines from California Dry Lakes for the Manufacture of Soda Ash by Carbonation"*, by F. H. May and M. L. Leonardi, presented before the AIME Los Angeles meeting, October 1949. Therefore, the balance of this paper will be confined to the main plant cyclic process.

## Main Plant Cyclic Process

*Concentration:* In the main plant cycle, raw brine from the storage tanks is mixed with process end liquors to become *evaporator feed* liquor, and, in theory at least, it is ultimately evaporated to dryness as it is recycled some 38 times through

Table I. Composition of Upper and Lower Structure Brines, as Pumped

| Constituent | Upper Structure, Pct | Lower Structure, Pct |
|---|---|---|
| KCl | 5.02 | 2.94 |
| $Na_2CO_3$ | 4.80 | 6.78 |
| $Na_2B_4O_7$ | 1.63 | 1.96 |
| $Na_2SO_4$ | 6.75 | 6.56 |
| NaCl | 16.06 | 15.51 |
| $Na_2S$ | 0.06 | 0.30 |
| $Li_2O$ | 0.015 | 0.006 |
| KBr | 0.12 | 0.08 |
| $WO_3$ | 0.007 | 0.004 |
| $I_2$ | 0.003 | 0.002 |
| $P_2O_5$ | 0.070 | 0.044 |
| F | 0.002 | 0.002 |

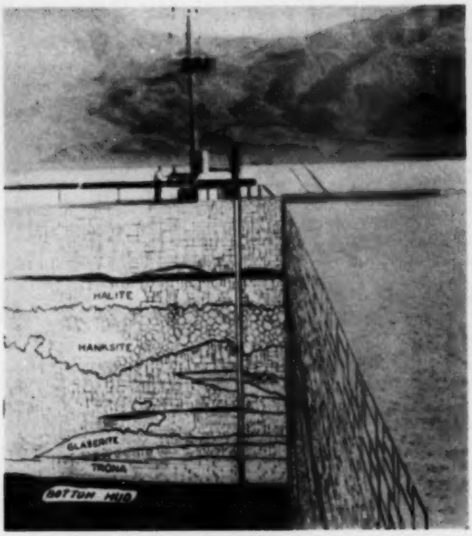


Fig. 2—Cross-section of upper salt deposit showing a typical well casing and pump mounting. The designation "Bottom Mud" is a misnomer and should properly read "Parting Mud" separating the upper 71-ft salt body from the lower 40-ft salt deposit, both of which are permeated with saturated brines.

triple effect counter-current evaporators and crystallizer units. Heat supply to the evaporators is 32-lb exhaust steam from turbo-generators, which are rated at 31,000 kva. The generators are driven by steam pressures ranging from 225 to 450 psi. Steam is generated by Babcock & Wilcox boiler units, which consume 1 bbl of oil per 1000 gal of raw brine pumped.

Evaporation of the brine results in the precipitation of sodium chloride from its saturated solution. In addition, heating and evaporation of the brine causes the precipitation of burkeite, a double sodium salt of carbonate and sulphate which is inversely soluble. As the precipitated salts are removed from the saturated liquor by suitable elutriation equipment, the liquor becomes increasingly concentrated with respect to the directly soluble potassium chloride and sodium tetraborate constituents. This concentrated liquor, thus freed of a good portion of the sodium chloride, carbonate, and sulphate, is allowed to become concentrated fourfold with respect to dissolved potassium chloride and sodium tetraborate values at a temperature of 220°F as it is discharged from the first effect evaporator.

*Potash Crystallization:* Potash crystallization is essentially a cooling, settling, and filtering operation wherein the concentrated liquor is diluted and then rapidly cooled to 100°F. Rapid cooling takes place in three-stage, vacuum, flash-coolers designed for approximately 20-min retention time.[3] The dilution of the hot liquor compensates for evaporation during vacuum cooling to prevent sodium chloride precipitation. Raw brine is used as the condensing medium because of its lower vapor pressure. Although the point of incipient borate precipitation under these conditions is 135°F, advantage is taken of the fact that borax tends to supersaturate. The muriate of potash crystals, thus precipitated relatively free of borate contamination, are thickened in cone settlers and filtered off in basket-type centrifugals. Approximately 650 tons per day of muriate of potash on an anhydrous basis are produced. It is given a displacement wash and is dried in rotary oil-fired kilns enroute to storage to await shipment as agricultural grade (61 pct $K_2O$) muriate of potash. A portion of the product is recrystallized to produce chemical grade muriate of potash. From this operation the KCl solution is treated in Kubierschky-type towers to remove bromine. The recovered bromine is refined and marketed as liquid bromine or alkali bromides of USP quality. A portion of the muriate production also is made into potassium sulphate by reaction with crude burkeite or sodium sulphate. Filtrate from the potash centrifugal baskets is combined with the cone overflow liquor and forwarded to the borax crystallizers.

*Borax Crystallizers:* At the borax plant, end liquor from the potash plant is diluted with a small amount of borax refinery end liquor and is distributed to six vacuum ammonia-cooled crystallizers equipped with Kinney pumps for the removal of N.C. gases, wherein the liquor is cooled to about 80° F.[3] At this lowered temperature, crude borax is precipitated and thickened. The thick sludge is filtered over Oliver filters. Filtrate from the filters is combined with overflow from the thickener and is pumped, via heat exchangers at the potash crystallizers, back to the main plant evaporator feed storage tanks. This completes the main plant cycle.

The crude borax filter cake is brine-leached to remove soluble phosphate impurities and then is

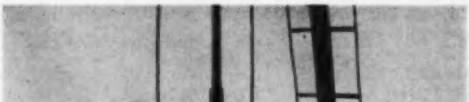

Fig. 3—48x9.5-in. core barrel 18-in. reamer, Sullivan model 22-HD core-drill in background.

recrystallized for the manufacture of refined borax. Part of the refined borax is treated with sulphuric acid to produce technical and USP grades of boric acid. In addition, a substantial portion of the refined borax production is dehydrated by heating ultimately to fusion temperatures in the recently expanded pyrobor plant to produce "Pyrobor," a crystalline anhydrous borax. Total borate production is 300 tons per day.

*Evaporator Tail Salts Processing:* At the main plant evaporators, such as that shown in Fig. 4, the sodium chloride is separated from burkeite by means of suitable elutriators designed to operate in series as hydraulic classifiers. Coarse sodium chloride material discharging from the underflow of this salt trap is washed free of its brine entrainment on vibrating screens and is sluiced back to the lake to the extent of 2500 tons daily. The burkeite fines, or sodium double salts of carbonate and sulphate, are filtered on Oliver filters and given a brine displacement wash with end liquors from the soda products plant. The washed filter cake, which amounts to approximately 1300 tons daily, is repulped in these same end liquors, which serve as a vehicle in transporting this raw material feed to the soda products plant.

## Soda Products Process

At the soda products plant, the burkeite double salt of sodium carbonate and sulphate is leached for free sodium carbonate in excess of that combined as burkeite in a cold saturator tank. The slurry is then treated with sodium chloride in a hot saturator tank equipped with steam coils for burkeite precipitation. The burkeite solids are then thickened, filtered, and dissolved in water. Because of its inverse solubility, dissolution of burkeite necessitates additional cooling equipment to operate in closed circuit with the dissolver to remove the evolved heat of solution characteristic of this material.

*Salt Cake Production:* The dissolved burkeite slurry, which is made up to analyze 30 pct of dissolved salts by means of sensitive pneumatic density-controlled devices, is passed through the lithium plant for the removal of undissolved lithium phosphate suspension. The clarified burkeite liquor is forwarded to glauber salt crystallizers, wherein the liquor is cooled to approximately 78°F. At this point of glauber salt precipitation, crystals are filtered and intermixed with sodium chloride in converter tanks. Anhydrous sodium sulphate or salt cake is thus produced by dissolution of sodium chloride in the water of hydration, which constitutes 56 pct by weight of the glauber salt mass. The reaction is endothermic and the degree of refrigeration so obtained is utilized in the barometric condensing system of the glauber salt crystallizers, thus forming a regenerative refrigeration cycle.

Filtrate from the glauber salt filters is forwarded via surge tanks to vacuum ammonia-cooled crystallizer tanks. Cooled crystallizer discharge is then forwarded to crude sulphate precipitator units, wherein treatment with sodium chloride results in the precipitation of much of the residual sodium sulphate. End liquors from these precipitator units are returned to the main evaporator plant for sluicing burkeite filter cake raw material feed to the soda products system. The crude sodium sulphate is thickened, filtered, leached for chloride impurity, and further thickened. Thickener overflow is discarded as sulphate end liquor, and the underflow is combined with the anhydrous sulphate production from the glauber salt crystallizers. This material is filtered and dried in rotary oil-fired dryers and stored in concrete silos at rates up to 600 tons per day to await shipment.

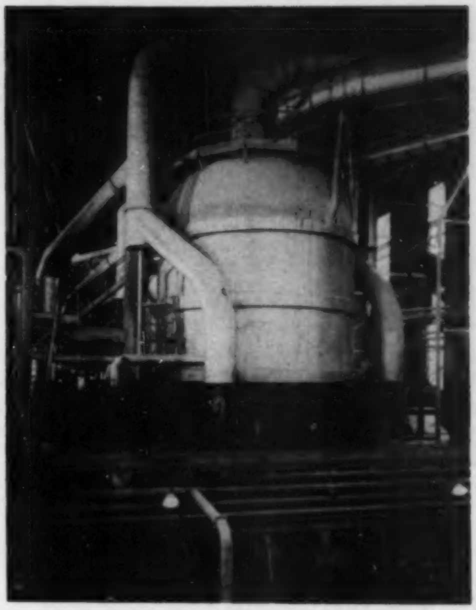

**Fig. 4—One of nine evaporator pans, which measure 58 ft high by 26 ft in diam. Note external heater units and vertical, turbine-type circulation pumps in lower foreground.**

*Soda Ash Production:* The 60-ft Dorr thickeners which are fed from the hot and cold saturator tanks and which discharge chloride-free burkeite underflow solids to the sulphate refinery were described. The clarified thickener overflow is combined with filtrate liquor from the burkeite filters to become raw material feed to the carbonate refinery of the soda products plant. This hot carbonate liquor is first cooled in two-stage barometric vacuum crystallizers for sodium chloride precipitation. The sodium chloride is thickened and routed where needed to the sulphate precipitators and/or hot saturator tank. The clarified liquor overflow from this settling cone is further cooled in ammonia vacuum coolers to crystallize sal soda, which is filtered and converted to sodium carbonate monohydrate in double effect steam-heated vacuum evaporators. This product is again filtered and fed to oil-fired rotary driers. The calcined soda ash is stored in concrete silos at the rate of about 300 tons daily.

*Lithium Production:* One of the minor coproducts of the main evaporative cycle from a tonnage standpoint is lithium sodium phosphate. The product analyzes 21 pct $Li_2O$ and constitutes the highest known grade of crude lithium material on the market. It is and will continue to be a major source of lithium for manufacture of lithium products.

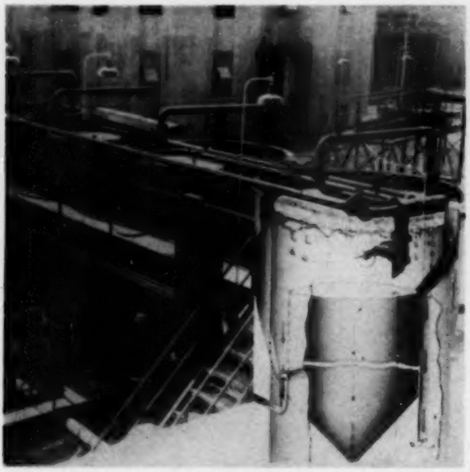

Fig. 5—Cross-section of one of four flotation tanks at lithium plant, showing inner tank construction, direction of liquor flows, and froth discharge.

The lithium content of the raw brine fed to the main plant evaporator cycle is 0.015 pct $Li_2O$. As a result of heating and concentration of the raw brine, the lithium is caused to precipitate mainly in the first effect evaporator as di-lithium sodium phosphate. The solid precipitate is extremely fine and averages 2.5 microns in particle size.

A fatty acid derivative is added in small amounts to the main evaporators to control foaming under vacuum concentration. This fatty acid saponifies in the hot alkaline medium, and the soap formed, together with the subsieve colloidal lithium material, becomes occluded by the inversely soluble burkeite precipitate. This material is freed from the burkeite at the burkeite dissolution step of the soda products process as previously outlined.

Thus, the lithium slime remains undissolved to a great extent in the burkeite liquor and is but slowly soluble, due, presumably, to its soap coating. In this condition the material is nonfilterable. It was once a troublesome and expensive plant problem, but an efficient method was devised for its recovery from burkeite liquor.

Up to 150 tons per month of this material are being recovered continuously by a unique flotation process. A light mineral oil is added to the burkeite dissolution tank. Aeration is introduced at the burkeite liquor cooling towers as the liquor is sprayed vertically downward through upward rising induced drafts of air. The air so introduced is emulsified by the soap and oil reagents present in the liquor as it is transferred via centrifugal pumps to the lithium flotation tanks.

Four 10,000-gal flotation tanks constitute the battery of flotation cells. A cross-section of one of these flotation tanks is shown in Fig. 5. These tanks are operated in parallel, stand 20 ft high by 9 ft diam, and are equipped with inner discharge cones and froth overflow launders. An automatic constant-level control device maintains constant head, which may be raised to yield froths of varying degrees of concentration. At other times, the level may be so adjusted as to rise at regular intervals and discharge the froth batchwise.

At the four flotation tanks, the burkeite liquor is allowed to become relatively quiescent. At the normal flows of 600 gal per min, it is relatively free of turbulence. Feed entry to the tanks is accomplished at the bases and discharge takes place by means of the inner cones. Each cone is tapered from 6 ft diam at the points of entry, 6 ft below the froth overflow lip, to 9-in. discharge at the base. As the liquor rises through the annular space surrounding the cone, the particles of soap-oil coated lithium compound contact extremely fine air bubbles and coagulate into floccules or clumps. These rise to the liquor surface in the form of a stable, dilute foam. The foam concentrates upon standing before it is discharged across the froth overflow lip. Clarified effluent from the flotation tanks is routed to the soda products sulphate refinery. This constitutes the lithium froth flotation process as developed at the Trona plant. The absence of an extraneous compressed air supply, the absence of moving parts, and the substitution for close attention through automatic control devices is extant. The proportioning of dilution and froth modifier reagent requirements in the burkeite liquor makeup step at the dissolver tank likewise is controlled by sensitive pneumatic density-controlled devices. These are made to operate under extreme variations of liquor flow rates.

The lithium foam is collected by gravity flow from the froth launders into receiver tanks. These tanks are equipped with circulating pumps and suitable steam heating equipment. By heating to a temperature of 150°F, the foam is de-aerated and the slurry is leached for sulphate impurities. It is then filtered batchwise on Sweetland filter presses. The filter cake is partially air-dried and then is put through steam-jacketed mixers for final drying to less than 2 pct moisture content. The dried concentrate is packed in 100-lb bags to await shipment.

This completes the main plant cycle of the American Potash and Chemical Corp. operations at Trona. The total production of high grade chemicals amounts to 650,000 tons annually. Trona continues to contribute high quality potassium chloride products for the farmer and the chemical manufacturer. Its output of soda ash as a basic heavy chemical and one of the most widely used industrial chemicals is being increased. Trona's borax and boric acid production, sold mainly to the glass and enamel industries, is steadily increasing. Salt cake is used principally in the kraft paper industry and in the manufacture of industrial and domestic detergents. Trona continues to be the major source of lithium for the manufacture of refined lithium products.

### References

[1] H. S. Gale: Salines in the Owens, Searles, and Panamint Basins, Southeastern California. U. S. Geol. Survey, *Bull.* 580-L, (1912).

[2] W. A. Gale: Chemistry of the Trona Process from the Standpoint of the Phase Rule. *Industrial and Engineering Chemistry*, (August 1938).

[3] R. M. Mumford: Potassium Chloride from the Brines of Searles Lake. *Industrial and Engineering Chemistry*. (August 1938).

[4] J. E. Teeple: The Industrial Development of Searles Lake Brines with Equilibrium Data. New York Chemical Catalogues, Inc., (1929).

[5] B. W. Dyer: Searles Lake Development. Colorado School of Mines, *Quarterly*, 45, No. 4B, (October 1950).

# aime NEWS

## Minnesota Millmen Form New Subsection

Members of the Minnesota Section of the American Institute of Mining and Metallurgical Engineers interested in ore dressing met on Wednesday, Mar. 28, at the Hotel Androy in Hibbing and organized a Mineral Dressing Subsection of the Minnesota Section of the Institute. The meeting was called and organized by Hugh D. Leach, Vice-Chairman of the Minnesota Section and 65 members were present. This is the first subsection to be organized of three that are planned for the Minnesota Section. The other two, still in the planning stage, are in the fields of mining and geology. A vigorous program, consisting of at least four meetings a year was outlined. The following slate of officers was elected:

*Chairman*, Fred D. DeVaney, Pickands, Mather & Co., Hibbing.

*Vice-Chairman*, Stephen E. Erickson, M. A. Hanna Co., Hibbing.

*Secretary-Treasurer*, Milton F. Williams, Jr., Oliver Iron Mining Co., Duluth.

## Hoover Foundation

The Herbert Hoover Foundation has recently been organized to own, operate, and control the boyhood home of Mr. Hoover in Newberg, Oregon, to restore it to its original condition, and to furnish it as nearly as possible as it was when Mr. Hoover lived there as a boy.

Bert Brown Barker, president of the Foundation, requests that interested AIME members send contributions to this project. These contributions are allowable income tax deductions not only federally but also in Oregon and California. All communications should be addressed to James F. Bell, Secretary, Oregon Section AIME, Portland Gas and Coke Co., Public Service Building, Portland 4, Oregon. The Oregon Section of the AIME has resolved to sponsor the collection of contributions, gifts, and Hoover mementos from Mr. Hoover's many friends and fellow members in the AIME who would like to see this old home preserved and made a national historic site. Such a project is a fitting tribute to one of the nation's great presidents.

## Geology Field Course

The Colorado School of Mines is offering a new and advanced graduate field course in mining geology from July 30 to Sept. 8. Students must be graduates of recognized institutions, have majored in geology and had acceptable previous training in geological field mapping or surveying.

Tuition for the six-week course is $50, payable at the beginning of the session. This does not include living expenses. Tents will be available but students must furnish their own sleeping bags or bed rolls and make their own arrangements for meals either in camp or at a nearby town. Applicants for admission should contact dean M. I. Signer, director of the summer sessions of the Colorado School of Mines, Golden, Colo. Each should submit a statement of previous experience and training including a transcript of graduate and undergraduate credits. The size of the group will be limited to between 15 and 30 students selected from applications received before May 19.

## Coming Events

**May 4, Anthracite Conference**, ninth annual meeting, Lehigh University, Bethlehem, Pa.

**May 4, AIME**, Lehigh Valley Section, annual dinner dance, Lebanon Country Club, Lebanon, Pa.

**May 7, AIME**, Mexico Section, American Club, Mexico City.

**May 7, AIME**, Florida Section, Lakeland, Fla.

**May 7-11, Greater New York Industrial Show**, 71st Regiment Armory, New York.

**May 9-11, Engineering Institute of Canada**, annual meeting, Mount Royal Hotel, Montreal.

**May 13-16, American Institute of Chemical Engineers**, regional meeting, Hotel Muehlebach, Kansas City, Mo.

**May 14-17, American Mining Congress Coal Mining Convention & Exposition**, Auditorium, Cleveland.

**May 18, AIME**, Columbia Section, Moscow, Idaho.

**May 21-22, American Zinc Institute**, annual meeting, Hotel Statler, St. Louis.

**May 22, AIME**, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

**May 23-24, American Society for Quality Control**, annual convention, Hotel Cleveland, Cleveland.

**June 4, AIME**, Mexico Section, American Club, Mexico City, Mexico.

**June 11-14, Armour Research Foundation of Illinois Institute of Technology**, Sheraton Hotel, Chicago.

**June 11-15, Conference on Industrial Research**, Columbia University, New York.

**June 11-15, ASME**, semi-annual meeting, Royal York, Toronto, Canada.

**June 15-16, AIME**, Central Appalachian Section, spring meeting, Cumberland Hotel, Middlesboro, Ky.

**June 18-20, American Congress on Surveying and Mapping**, annual meeting, Hotel Shoreham, Washington, D. C.

**June 18-22, ASTM**, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

**June 23, AIME**, Colorado Section and Subsections, Ouray, Colo.

**July 30-Aug. 2, American Electroplaters' Society**, Statler Hotel, Buffalo.

**Aug. 7, AIME**, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

**Aug. 27-Sept. 6, Oak Ridge National Laboratory and Oak Ridge Institute of Nuclear Studies**, summer symposium, Oak Ridge.

**Sept. 13-15, AIME**, Industrial Minerals Div., fall meeting, University of West Virginia, Morgantown, W. Va.

**Sept. 16-19, American Institute of Chemical Engineers**, regional meeting, Sheraton Hotel, Rochester, N. Y.

**Sept. 18, AIME**, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

**Sept. 25-28, ASME**, fall meeting, Radisson Hotel, Minneapolis.

**Oct. 1-4, Assn. of Iron and Steel Engineers**, annual convention, Hotel Sherman, Chicago.

**Oct. 3-5, AIME**, Petroleum Branch, fall meeting, Oklahoma City.

**Oct. 10-11, Joint Fuels Conference, AIME**, Coal Div. and **ASME**, Fuel Section, Hotel Roanoke, Roanoke, Va.

**Oct. 15-17, AIME**, Institute of Metals Div., fall meeting, Detroit-Leland Hotel, Detroit.

**Oct. 15-19, National Metal Congress & Exposition**, Detroit.

**Oct. 19-20, Engineers' Council for Professional Development**, annual meeting, Hotel Statler, Boston.

**Oct. 22-24, American Mining Congress**, Metal and Nonmetallic Mining Convention, Biltmore Hotel, Los Angeles.

**Oct. 25-26, AIME**, Los Angeles Section, fall meeting, Los Angeles.

**Oct. 29-Nov. 3, AIME**, fall meeting, Mexico City.

**Oct. 30, AIME**, Morenci Sub-section, Longfellow Inn, Morenci, Ariz.

**Nov. 2, AIME**, Pittsburgh Section, annual off-the-record meeting, Wm. Penn Hotel, Pittsburgh.

**Nov. 25-30, ASME**, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

**Nov. 28-30, Scientific Apparatus Makers Assn.**, midyear meeting, industrial instrument, laboratory apparatus, laboratory equipment, optical, nautical, aeronautical, and military instrument sections, Hotel New Yorker, New York.

**Dec. 2-5, American Institute of Chemical Engineers**, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

**Dec. 6-8, AIME**, Electric Furnace Steel Conference, William Penn Hotel, Pittsburgh.

# Six-Day Mexico City Meeting Scheduled for October

MEXICO CITY will be the scene of an inter-American convention on mineral resources to be held from Oct. 29 to Nov. 3, 1951—a meeting in which AIME and three other engineering groups will take part. Mexico's first National Congress on Mineral Resources, a special meeting of the South Texas Geological Society, and a meeting of the Pan-American Institute of Mining Engineering and Geology (IMPIMIGEO or PAIMEG) will be the other groups represented.

All the societies at the meeting are planning to present papers on North and South American mineral deposits, but strictly technical sessions are being held to a minimum. Field trips and sightseeing are to be accented. The quality of technical papers presented will, of course, be high. At least four Divisions of AIME—Industrial Minerals; Minerals Beneficiation; Mining, Geology, and Geophysics; and Mineral Industry Education—will hold sessions in Mexico's capital.

Attendance at the meeting is expected to be large, and those who plan to attend should make their hotel reservations early. All prices, including hotel accommodations, average about one third lower than U. S. prices. Mexico City's newest and finest hotel, the Del Prado, is offering single rooms at prices ranging from $3.50 to $8 per day, and double rooms at $4.50 to $8.50 per day. The Geneve, a 450-room hotel, has singles from $1.75 up to $4.75, and doubles ranging from $3 to $6. The Ritz is offering singles at from $2 to $3.50, doubles from $4 to $7. There are many other excellent hotels in town, with varying price ranges. The Ritz and Geneve represent average prices for good accommodations; the Del Prado is the most expensive and luxurious.

MINING ENGINEERING readers are herein offered an opportunity to send their reservations directly to Bill Kane, Secretary of the Mexico City Section. Fill out the coupon, send it directly to Mr. Kane, and be assured of reservations at the price you want to pay.

### Mexico City Meeting Program
### Oct. 29 to Nov. 3, 1951

**Monday, Oct. 29**

**Opening Session.** Palace of Fine Arts. Addresses by Miguel Aleman, President of Mexico, and Raul de la Peña, Convention Director.

**Opening Luncheon.** Address by Fernando Casas Aleman, Governor, Federal District.

**Tuesday, Oct. 30**

**Technical Sessions.** 10 am to 1 pm; **Lunch.** 1 pm; **Technical Sessions.** 4 to 6 pm.

**Wednesday, Oct. 31**

**Technical Sessions.** 10 am to 1 pm; **Luncheon.** 1 pm; **Technical Sessions.** 4 to 6 pm; **Dinner and Dance at El Patio Night Club.** 8 pm.

**Thursday, Nov. 1**

**Final Sessions.** Address by AIME President W. M. Peirce. 11 am

**Lunch** at Xochimilco Floating Gardens. 2 pm.

**Excursions** Near Mexico City. 4 to 7 pm. The pyramids of Teotihuacan, El Caracol, Shrine of Guadalupe, and other points of interest. Beginning of trip to Taxco and the American Smelting & Refining Co. operations.

**Friday, Nov. 2**

**Trip to Taxco.** 9 am. Luncheon will be served by the American Smelting & Refining Co.

**Trip to Pachuca.** Luncheon courtesy of Cia. de Real del Monte.

**Saturday, Nov. 3**

**Optional out of Town Trips:** Acapulco, seacoast resort; Morelia, Patzcuaro, Uruapan, Paracutin volcano; Pueblo, Orizaba, Fortin, and Veracruz; Oaxaca and Monte Alban and Mitla relics; Guanajuato, colonial mining center. These trips may occupy more than one day.

**Mr. William G. Kane**
**San Juan de Letran 9-805**
**Mexico, 1, D.F.**

Please make the following reservations for me for the October meeting:

Single Room ........ Double Room with twin ........
double ........ beds, at about $.......... per day. There will be .......... men and .......... ladies in my party.
Expected date of arrival ..........; departure ..........
..........................................................................

Name ..........................................................

Title and Company ......................................

Street .........................................................

City, Zone, State ..........................................

MES

# Performance pays . . .

**Mill operators are judged by results. For the man who must be shown, here are some more actual test figures.**

## Case No. 7

Tests at a mining operation grinding sulphide copper ore.

*Service:* Marcy 6′ × $4\frac{1}{2}$′ ball mills grinding a high sulphide ore from minus $\frac{3}{4}$″ to minus 14 mesh. Balls charged were 5″ dia.

*Comparison:* For many years the company used austenitic manganese steel liners in its mills. Then a change was made to high carbon chromium-molybdenum steel liners, normalized and tempered to 360 Brinell.

*Liner type:* Shell (barrel) liners, wave type.

| **Results:** | **Tonnage ground** |
|---|---|
| **Austenitic manganese steel (average)** | **75,000** |
| **Cr-Mo steel (average)** | **84,000** |

## Case No. 8

Tests at a mining operation grinding gold-bearing quartz ore.

*Service:* Marcy 6′ × 7′ overflow type mill grinding $\frac{3}{4}$″ feed.

*Comparison:* One set of manganese steel liners was run till worn out, and followed by one set of high carbon chromium-molybdenum steel liners run under similar conditions.

*Liner type:* Shell (barrel) liners, wave type.

| **Results:** | **Life— Days** | **Tonnage Ground** |
|---|---|---|
| **Manganese steel liners** | **148** | **48,932** |
| **Cr-Mo steel liners** | **212** | **74,794** |

The chrome-molybdenum steel liners showed an increased tonnage ground of 53%.


Write for 32 pp reprint of an informative paper published by the Amer. Inst. of Mining and Metallurgical Engrs., giving results of wear tests on grinding ball materials—FREE!

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MOLY

MIE5

# *Drift of Things* . . . . . . . . as followed by **Edward H. Robie**

EFFORTS made by the national engineering societies and other professional organizations to see that professional and technical skills are utilized by the nation to better advantage in the present emergency than they were in World War II seem to be bearing fruit. Engineers Joint Council, of which the AIME is one of the five constituent societies, has been working actively to this end through its Engineering Manpower Commission. A representative from each of the three Branches of the AIME is on the Commission. The Commission's efforts have been centered in two directions: 1—To utilize present professional skills to the best advantage of the country, and 2—To provide for a continuing adequate supply of graduate engineers.

On March 31, President Truman issued an Executive Order amending the former Selective Service regulations. Thereby, all registrants would be deferred from military service if they are 1—engaged in research, medical, scientific, or other endeavors necessary to the maintenance of the national health, safety, or interest; 2—if the registrant cannot be replaced, because of a shortage of persons possessing his qualifications for such service; and 3—if removal of the registrant would cause a material loss in the effectiveness of the vital activity in which he is engaged. Presumably, Draft Boards will be given specific direction as to what endeavors are "necessary to the maintenance of the national health, safety, and interest."

All students above a certain level of standing in their classes or whose score is sufficiently high in aptitude tests would be deferred. These levels have not yet been determined, the idea being that they will be raised or lowered as the demand for students in training changes. A grade of 70, or C, in college has been mentioned. It is believed that substantially all freshmen accepted for college entrance this fall will be deferred; about half of next year's sophomore class; two thirds of the juniors; three quarters of the seniors; and all full-time graduate students. Thus would be deferred perhaps 800,000 male non-veteran students. Objection has been offered to this rather wholesale deferment by numerous newspaper editors. They argue, rather convincingly, that the standards demanded are too low, that many students are taking curricula of no practical value in the present emergency, that many of those deferred are anything but outstanding students and unlikely ever to be of any exceptional value to the country for special needed skills, and that many equally promising boys are not in college. Also, they argue, much less convincingly, that this deferment of college students is a departure from the idea of universal military service. So it is, but that is the idea that we are trying to get across: That people with exceptional brains are more valuable to the country if they utilize these brains in productive ways than if they use them in military combat, wherein many would be lost.

As to the aptitude tests, they will be conducted at some 1000 centers on May 26, June 16, and June 30. The cost to registrants will be nil, except for traveling expenses to the testing center. There will be no second chance if the testee fails. The tests will be conducted by the Educational Testing Service of Princeton, N. J. (no connection with Princeton University). This organization has had wide experience in this field and customarily makes over a million aptitude tests a year.

The Engineering Manpower Commission should have available by May a bulletin giving in detail exactly what should be done by an employer who wishes to retain the services of a young man subject to the draft. In general, nothing should be done until the employee receives notice of forthcoming induction.

### Technical Men in the Army

A few months ago an AIME member told us that a young man, upon induction into the Army, could request transfer to the Technical Services Command, and would then be sent to Fort Belvoir, Va., where he would be trained along the lines of his former schooling and experience. We followed this up, and received the following letter from Major General Edward F. Witsell, of the Adjutant General's office, Washington:

"There is no Technical Services Command. It is believed that your inquiry is in connection with technical services which are the Corps of Engineers, Signal Corps, Quartermaster Corps, Ordnance Corps, Chemical Corps, Transportation Corps, and Army Medical Service.

"The Department of the Army is making every effort to assign personnel where the fullest use may be made of their training and experience. All individuals upon induction are required to complete the course in basic training at one of the training centers and are not assigned to a post or unit until this course has been completed. This ensures that each enlisted man is properly trained in the event of combat and also enables the Army to determine how and where his abilities may be utilized to the fullest extent in meeting the needs of the services."

### From an Englishman

Honorary Members of the AIME, whose number is limited to 20 living individuals, are always invited to sit at the head table at the Annual Banquet of the Institute. A few are able to come, and the invitation usually produces appreciative letters from some of those who can't. From C. McDermid, long a secretary of both the Institution of Mining Engineers, which is devoted to coal, and the Institution of Mining and Metallurgy, in London, came this message in January: "The invitation inspires afresh the great pride I have always felt for the honour conferred upon me by the Institute so many years ago; and brings comfort to me, in these truly horrible and anxious times, by reminding me that in my old age I still have a material, as well as a spiritual, connection with your great country. Without its unswerving will and all-powerful support all that we and the rest of the free peoples hold sacred would be doomed to destruction, and the world to domination by the Devil for perhaps centuries to come!"

### Sign of Senility

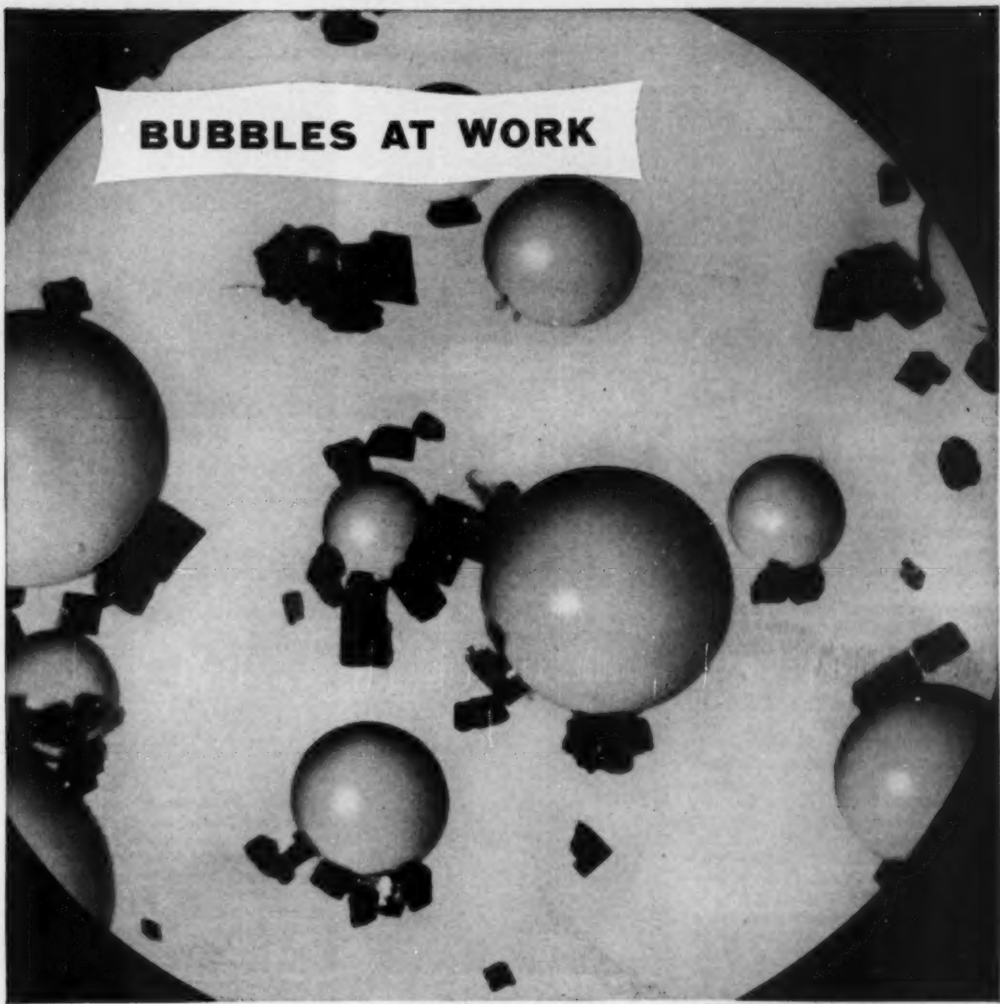
A verse that we were handed the other day reads as follows:

You're not getting old
When your hair gets gray;
You're not getting old
When your teeth decay.
But, boy, you're headed
For the last long sleep
When your mind makes plans
Your body can't keep.

Well, we think it would be even more serious if the last two lines read as follows:

When your body is willing
But your mind is weak.

Maybe not as good rhyming though.




Photomicrograph, greatly enlarged, by H. Rush Spedden

To help step-up flotation recoveries at low cost, Hercules has developed a number of frothers and collectors. Yarmor® F Pine Oil has been a standard of quality among pine oil frothers since the early 1920's. RADA (Hercules' Rosin Amine D Acetate) is a siliceous mineral collector that has good solubility and is easy to handle. It is used in the commercial flotation of several nonmetallic ores. These and other Hercules products are described in a 16-page technical booklet, "Flotation and Hercules Flotation Agents." This booklet also contains many formulas useful in the operation and control of modern ore-dressing mills. *Send for your copy.*


*HERCULES POWDER COMPANY* *955 King St., Wilmington, Delaware*

**HERCULES** Flotation Agents

NM51-1

# Personals

**Francis M. Aimone** recently joined the staff of the mineral dressing laboratory of American Cyanamid Co., Stamford. Prior to joining Cyanamid, he was in charge of the Casapalca concentrator of the Cerro de Pasco Copper Corp. in Peru.

**Carl W. Appelin** has resigned as mine shift boss with the American Smelting & Refining Co. of Parral, Chih., Mexico and is presently connected with the engineering dept. of the Phelps Dodge Corp., Ajo.

**Anders E. Augustson** is now associated with the Calera Mining Co., Forney, Idaho.

**Gordon T. Brown** has joined the Copper Canyon Mining Co., Battle Mountain, Nev.

**Horace D. Bevan** has resigned as chief engineer, Cia Huanchaca de Bolivia, Pulacayo, Bolivia. He is planning a visit to Chile before returning to the United States.

**Charles H. Behre, Jr.** and **Parke A. Hodges** of Behre Dolbear & Co., New York, are in Haiti where they are engaged in professional work for the government of that country.

**Charles A. Brokaw** is now connected with the Eastman International Co., Denver.

**Charles Rice Bourland** has been made vice-president of the New River Co., Mt. Hope, W. Va.

**Roy Hardeman Barnes** is now general manager-operator of the Tom Reed-Allison Mine, Pima County, Ariz.

**Hugh H. Bein,** formerly with the Lepanto Consolidated Mining Co., Mankayan, Mt. Prov., P. I. is now residing at Sacramento.

**Bernard Allen Bramson** is leaving his position as supervisor of ores and metals for the import div. of Westinghouse International to accept the appointment as minerals attache to the west coast of South America. His new headquarters will be at the U. S. Embassy, Lima, Peru.

BERNARD A. BRAMSON

**F. H. Kihlstedt** is now in charge of the mining dept. of Orinoco Mining Co., New York. He was previously in charge of operations in Venezuela of the above company and its predecessor, a branch of Oliver Iron Mining Co.

**Donald H. McLaughlin,** 1950 President of AIME, was appointed to the Board of Regents of the University of California.

**R. L. McCann** has been elected president of the New Jersey Zinc Co., succeeding **Henry Hardenbergh,** who was elected chairman of the board of directors. Mr. McCann was formerly general manager of mines and has been vice-president since March 1950.

**Jean McCallum** is now associated with the Combined Metals Reduction Co., Salt Lake City.

**G. W. Nielsen** was elected to "Who's Who on the Pacific Coast" for his method in extracting magnesium oxide from magnesite ore at the Basic Magnesium plant at Gabbs, Nev.

JOHN F. THOMPSON

**John F. Thompson,** president of the International Nickel Co. of Canada, Ltd., was elected to the office of chairman of the board of directors, succeeding the late **Robert C. Stanley. Paul D. Merica,** executive vice-president and director, International Nickel Co. of Canada, Ltd., was elected a member of both the executive and advisory committees.

**H. H. Uhlig,** head of the corrosion laboratory, MIT, Cambridge, will receive the 1951 Willis Rodney Whitney Award for his contribution to the science of corrosion.

**Marvin J. Udy,** consultant in metallurgical and electrochemical engineering, has been elected vice-president of the Electrochemical Society, New York. **J. C. Warner,** president of the Carnegie Institute of Technology, Pittsburgh will also serve as vice-president.

J. R. VAN PELT

**J. R. Van Pelt** has been named president of the Montana School of Mines at Butte. Dr. Van Pelt has been identified with engineering education and research since his graduation from the Michigan College of Mines in 1922. He has been associated with the Rosenwald Industrial Museum in Chicago, now known as the Museum of Science and Industry, and also Battelle Memorial Institute. He holds B.S. and E.M. degrees from Michigan College and A.B. from Cornell of Iowa, and in 1942 the ScD. degree was conferred upon him by the latter. Dr. Van Pelt served as a director of AIME from 1941 to 1947 and as a vice-president from 1944 to 1947.

**William O. Vanderburg,** minerals attache, American Embassy, Pretoria, South Africa, returned to the United States for a short time before leaving for Paris. He has been transferred to the Office of the Special Representative, ECA, Paris, on a loan basis from the State Dept. He will be working on the investigation of deposits of deficiency minerals in the Scandinavian countries, western and southern Europe, and the African continent.

**Santiago E. Vera** is now associated with the Ministerio de Minas e Hidrocarburos, Caracas, Venezuela.

**John Varga, Jr.** is now employed as a research engineer with Battelle Memorial Institute, Columbus.

**N. de Voogd** has accepted a position as mine superintendent with the Comite Nation du Kivu, Belgian Congo. He has been located in South America for approximately 18 years.

**George Vassilopoulos** is now employed by the Wright Aeronautical Corp., Woodridge, N. J.

**Sherman A. White** has joined the Cia Minera de Oaxaca, Tlaxiaco, Oaxaca, Mexico.

**Raymond E. Wilkie** has left the Fiji Islands and returned to Montreal. He may be reached c/o Bank of Montreal, 1-193 St. Laurent, Montreal 9.

**William H. Wilson** has been employed by the ground water branch of the U. S. Geological Survey, Tucson as a geologist.

**Clifford Wendel** has joined Patino Mines & Enterprises Consolidated, Inc., Catavi, Bolivia.

**Edward Wisser** has formed an association with **K. G. Schwegler,** mining and geological consultants. They are located at the Acheson Bldg., Berkeley, Calif.

**Raymond E. Zimmerman,** consulting engineer for the Koppers Co. has been in the U. S. temporarily, but plans to return to Zonguldak, Turkey.

## Obituaries

**John Scott Hemphill** (Member 1935) died on April 2 after a few hours' illness. Mr. Hemphill was born in 1901 at Murton, England. He came to the United States and was reared in Benton, Ill. He was graduated from the University of Illinois in 1926. Following graduation he joined the Union Colliery Co. as engineer on mechanical coal loading machines. Several years were spent prospecting for private parties in French West Africa and in 1931 he had part time charge of quarry and plant for the U. S. Gypsum Co. at Farnams, Mass. For several years he was associated with the American Cyanamid Co. in Andersonville, Ga. In 1936 he was employed by the Cerro de Pasco Copper Corp. in Peru and then joined the Frederick Snare Corp., Mollendo, Peru. He held positions with mining companies in various parts of the United States and abroad. At the time of his death he was a project engineer with the Georgia Highway Dept. stationed at Lexington, Ga. He was planning to leave there for Grand Junction, Colo. where he had accepted a position in the Raw Materials Operation of the U. S. Atomic Energy Commission.

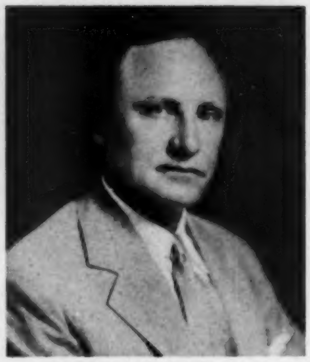
### Appreciation of Brent N. Rickard

By Howland Bancroft

Brent Neville Rickard, metallurgist, AIME Member 1907, Director 1934-1940, retired operating executive of the American Smelting & Refining Co., died on Mar. 8, 1951 in Tucson, Ariz. of cancer of the lungs. Brent was born in Anaconda, Mont. on June 28, 1885 of English-Irish parents, Stephen and Constance Neville Rickard, early friends of a gentleman from Sweden who came to America in his early manhood and who later became the foremost mining geologist of his time, Waldemar Lindgren. Brent's maternal grandmother, Mrs. Neville, arrived in San Francisco in 1856 and lived there

throughout its growth from that time until 1904 when she joined Brent's parents in residence in Denver. The California Historical Society, through the thoughtful courtesy of Brent, is now the possessor of some 40 large scrapbooks and 12 albums in which Mrs. Neville recorded interesting events in that colorful era of San Francisco's history.

During Brent's early childhood his parents moved from Anaconda to Denver where young Brent, during the time he was attending public schools in Denver, also learned assaying from his father, a chemist and assayer of repute. Brent was thus equipped to earn a living while still a student in the Denver Manual Training High School and he put his knowledge and skill in assaying to early use by leaving college in order to assist in financing the collegiate education of his two brothers. While his formal education was thus limited to one year in the University of Michigan his practical technical education through experience was continuous from the time he first bucked a sample for his Dad until he retired after 40 years of continuous service with the American Smelting & Refining Co. during which time he rose from chemist to metallurgist to assistant superintendent to superintendent to assistant manager and finally to manager of different units of the smelting branch of that corporation.



BRENT N. RICKARD

Brent's adult life was spent in Mexico and in the Western part of the United States. A chronological summary of his professional career is to be found in *Who's Who in Engineering* as well as in *Who's Who in America* where details regarding his various assignments along with corresponding dates are available. However, these publications quite naturally make no mention of his personal characteristics and it is the purpose of his brief appreciation to bring some of these to the attention of those not fortunate enough to have had personal contact with a man who spent his life doing things for others. All who really knew Brent were fully aware of the continuity of his service to mankind.

Brent was the prospectors' and small mine operators' friend and confidant. None of their problems were too small for his serious and considerate attention. He thought of public service as a duty to be cheerfully performed and his participation in many public activities endeared him to the hearts of youngsters and earned him the appreciation and gratitude of his fellow citizens. He took a very active part in the affairs of the American Institute of Mining and Metallurgical Engineers and of the American Mining Congress in whatever part of the United States he happened to have headquarters, and these organizations benefited greatly from his association.

During World War II Brent was "loaned" to Metals Reserve Co. from time to time to assist in some of their activities and his help was greatly appreciated by those with whom he came in contact.

Brent was a truly remarkable husband, a wonderful and thoroughly appreciated father and he had the good fortune to witness the early years of five grandchildren. In the words of one of the many young people he helped along the way Brent was truly an *honorable* man. The world is better off for his having lived in it.

## NECROLOGY

| Date Elected | Name | Date of Death |
|---|---|---|
| 1946 | George E. Addy | Sept. 24, 1950 |
| 1938 | H. C. Howarth | Feb. 18, 1951 |
| 1932 | Sam A. Lewisohn | Mar. 13, 1951 |
| 1928 | Emmet F. Meyerhoff | Unknown |
| 1906 | Robert H. Morris | Mar. 1, 1951 |
| 1909 | Andrew W. Newberry | Feb. 3, 1951 |

# Proposed for Membership

## MINING BRANCH, AIME

*Total AIME membership on Feb. 28, 1951 was 17,054; in addition 4580 Student Associates were enrolled.*

*ADMISSIONS COMMITTEE*

*Thomas G. Moore, Chairman; Carroll A. Garner, Vice-Chairman; George B. Corless, F. W. Hanson, Albert J. Phillips, Lloyd C. Gibson, R. D. Mollison, John T. Sherman. Alternates: A. C. Brinker, H. W. Hitzrot, Plato Malozemoff, Ivan Given, T. D. Jones, and W. H. Farrand.*

*Institute members are urged to review this list as soon as the issue is received and immediately write the Secretary's Office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified. Objections must be received before the 30th of the month on Metals and Mining Branches.*

*In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; AM, Associate Member; S, Student Associate.*

**Alabama**
*Birmingham*—Peterson, Leonard W. (M)
*Flat Creek*—Hastings, James V. (J) (C/S—S-J)

**Arizona**
*Ray*—Duncan, Donald M. (J)

**Arkansas**
*Malvern*—Sandell, William G. (M) (R. C/S—S-M)

**California**
*Fontana*—Brown, Frank (M)
*Pasadena*—Cassell, Andrew T., Jr. (J) (C/S—S-J)

**Colorado**
*Climax*—Lucke, Edward W. (J)
*Denver*—Carlile, Jessie C. (M) (C/S—A-M)
*Denver*—Cluck, Charlie E. (J)
*Denver*—Hurtado, Julio E. (M) (C/S—S-M)

**Florida**
*Lakeland*—Dressner, Elliott F., Jr. (R. C/S—S-J)

**Idaho**
*Smelterville*—McKinley, Charles A. (M)

**Illinois**
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*Chicago*—Piros, Robert J., Jr. (J)
*Chicago*—Severtson, Vernon S. (J)
*Quincy*—Caverly, Jefferson A. (M) (C/S—J-M)
*Sesser*—Glover, Thomas O. (J)

**Kentucky**
*Garrett*—Patton, Carmal (J)
*Hazard*—Mitchell, Peyton L. (M)

**Louisiana**
*Shreveport*—Clark, Charles C. (M)

**Massachusetts**
*Cambridge*—Mahadevan, Calamur (M)
*Chelmsford*—Shea, Vincent H. (M)
*Framingham Centre*—Sinisalo, Aarre (A)

**Michigan**
*Negaunee*—Nora, Peter D. (J)

**Minnesota**
*Aurora*—Calaman, Joseph J. (M)
*Minneapolis*—Stowasser, William F., Jr. (J)
*Minneapolis*—Vozoff, Keeva (J)

(Continued on page 462)






**Missouri**
*Kansas City*—Clayton, Walter C. (A)

**Nevada**
*Tungsten*—O'Keefe, Daniel A. (M) (C/S—J-M)

**New Jersey**
*Ogdensburg*—Hallen, Leslie G., Jr. (J) (C/S—S-J)

**New Mexico**
*Albuquerque*—LeBaron, Philip M. (M) (R. C/S—J-M)
*Carlsbad*—Doss, Walter R. (A)
*Hanover*—Tilney, Albert A. (J) (C/S—S-J)
*Hurley*—Souder, Arnold, Jr. (J)

**North Carolina**
*Raleigh*—Blake, Daniel (M)

**Ohio**
*Columbus*—Wesner, Adam L. (M) (R. C/S—J-M)

**Pennsylvania**
*Indiana*—Sherwin, Lee A. (M)
*Wilkes-Barre*—Lamont, Paul C. (A)

**South Dakota**
*Lead*—Voelker, Mervin J. (M)
*Rapid City*—Hayes, Joel P. (M) (R. C/S—J-M)

**Tennessee**
*Isabella*—Arpi, William A. (J) (R. C/S—S-J)

**Utah**
*Eureka*—Watt, Robert E. (A)
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**Virginia**
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**West Virginia**
*Fairmont*—Bobella, John C. (J) (C/S—S-J)
*Fayette*—Morton, Paul (M) (C/S—J-M)

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**Argentina**
*De Jujy*—Hansen, Gale A. (J)

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*Vancouver*—Kneen, Thomas (J) (R. (C/S—S-J)

**Canada**
*Sheep Creek, B.C.*—Morton, Norman A. (M) (C/S—J-M)

**Chile**
*Rancagua*—Bosio, Guido (M) (C/S—A-M)
*Rancagua*—Nedwick, Harry E. (J) (C/S—S-J)

**Cuba**
*Havana*—Castro, Carlos F. (J) (C/S—S-J)

**India**
*Rajkot*—Saurashtra-DePandya, Manhar J. (M)

**Japan**
*Hokkaido*—Nakajima, Shigeru (A)

**Mexico**
*D. F.*—Carty, John T. (A)
*D. F.*—Christian, George L. (A) (R. C/S—M-A)
*Guanajuato*—Calderon, Francisco L. (J)
*Napoles*—Bonillas, S. Ygnacio, (M) (R.)

**Netherlands**
*Baarn*—Graadt van Roggen, August H. (J) (C/S—S-J)

**Peru**
*Yauricocha Via Pachacayo*—Birkbeck, James M. (M) (C/S—A-M)

**Philippine Islands**
*Manila*—Lewis, Dan E. (J) (R. C/S—S-J)

**Portugal**
*Oporto*—Cerveira, Alberto DeM. (M) (C/S—A-M)

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*Mysore State*—Lillicrap, Donald H. (A)

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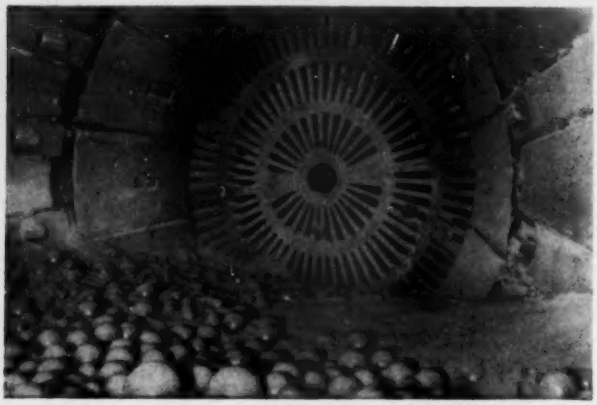
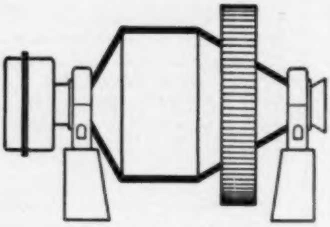
# NATURAL BALL SEGREGATION

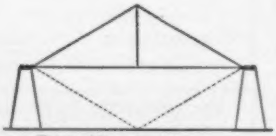


Here's what you see inside a Hardinge Conical Ball Mill. This unretouched photo shows the discharge end of the mill. Notice that all the large balls are in the foreground, near the feed end of the mill (where they belong for most efficient grinding).

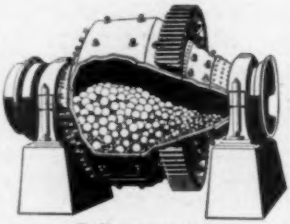


Less dead weight . . .

No dead corners . . .



Truss-like structure . . .



Ball segregation

Write for Bulletin 17-B-2 describing Conical Mills for dry grinding — Bulletin AH-389-2 for wet grinding.

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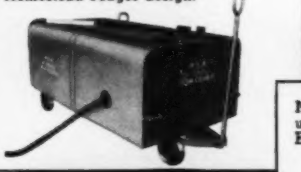

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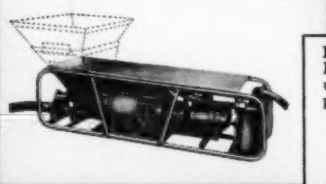

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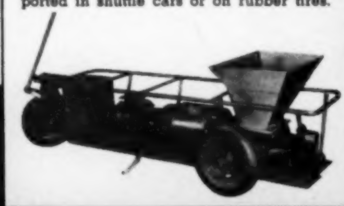

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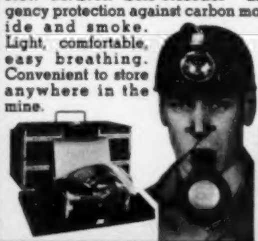

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